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Indian Journal of Power & River Valley Development

PROGRESS...THROUGH POWER!

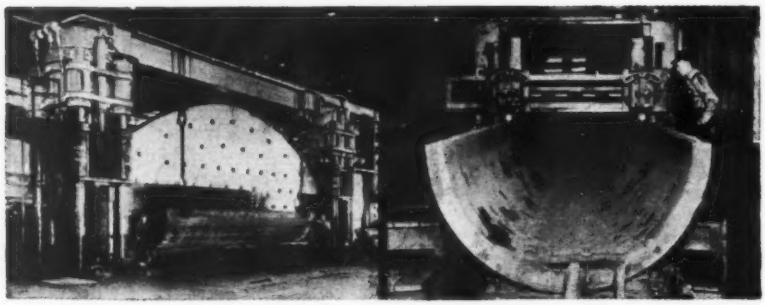
DATE DUE F-41

boilers for D.V.C.
nerate steam
at 1,920,000 lb/hr

In close cooperation with Damodar Valley Corporation, Combustion Engineering, Inc. is now at work on two huge steam generating plants for D.V.C.'s new Chandrapura Station.

The twin units will have a combined capacity of 1,920,000 pounds of steam an hour – delivered at a pressure of 2,190 pounds a square inch to two 125,000-kilowatt turbines. Nothing in India can compare with these modern "reheat" boilers for size and capacity. And . . . similar, additional units are planned for D.V.C.

This important phase of India's third five-year plan comes at the program's beginning. Combustion Engineering takes pride in its part in the Chandrapura Station, and in the many other C-E power plants installed in India during the past decade.



ONE REASON WHY C-E is frequently picked for big boiler jobs is C-E's vast facilities for heavy metal fabrication. *At left:* 6,000-ton press for the precision bending of steel plate in lengths up to 40 feet and thicknesses up to 9⅝ inches. *At right:* Planing the edges of a formed plate, to become one half of a welded boiler drum. C-299

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ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS; PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE

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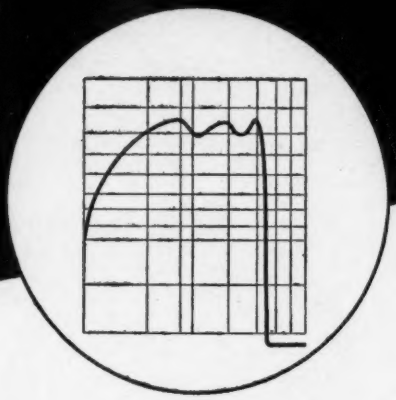

Time saving instruments

find always an important place in the development, manufacturing and testing of communication networks, because the measuring values of level, loss, impedance etc. as a function of frequency are reproduced instantaneously on the Cathode Ray Tube. Along with other instruments it is possible to localise the faults on transmission lines and to take routine measurements without interrupting the operation of multi-channel carrier telephone circuits.

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Sweep frequency oscillator and level tracing receiver

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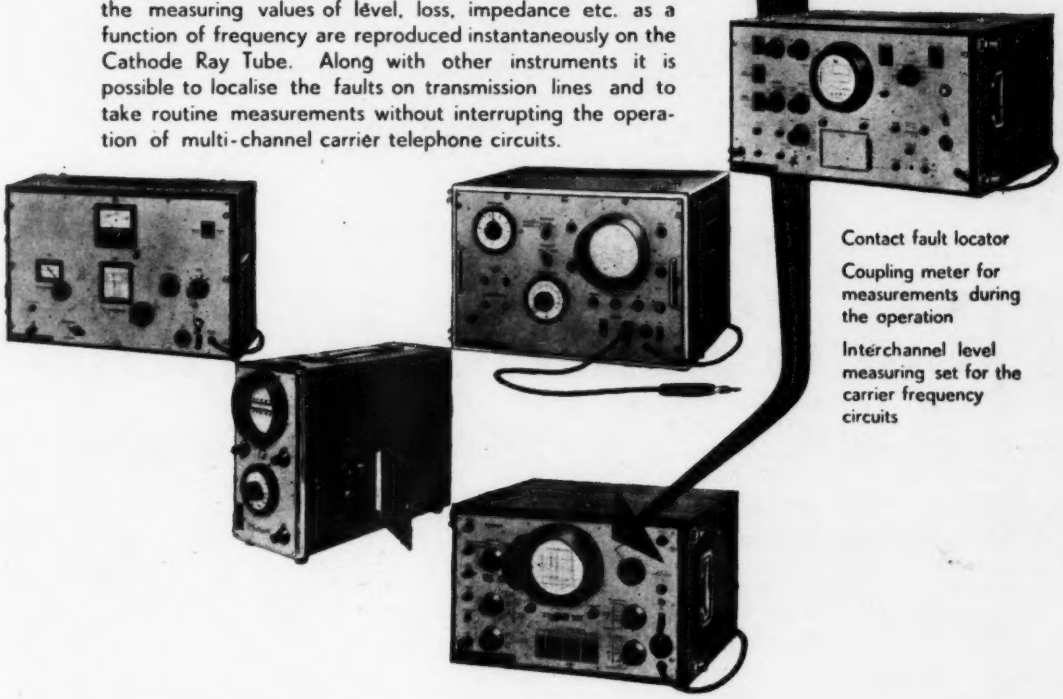

Contact fault locator

Coupling meter for measurements during the operation

Interchannel level measuring set for the carrier frequency circuits

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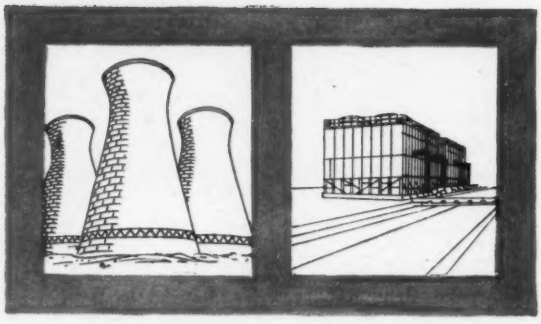

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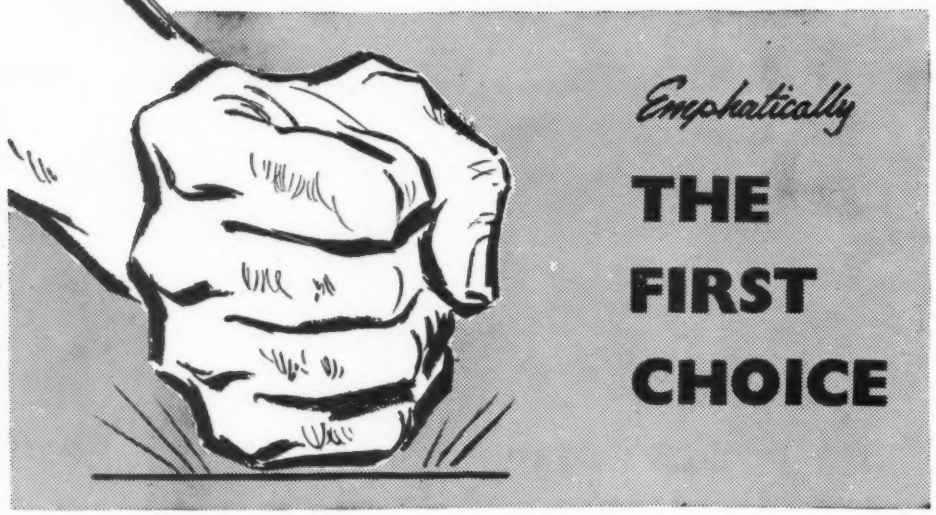

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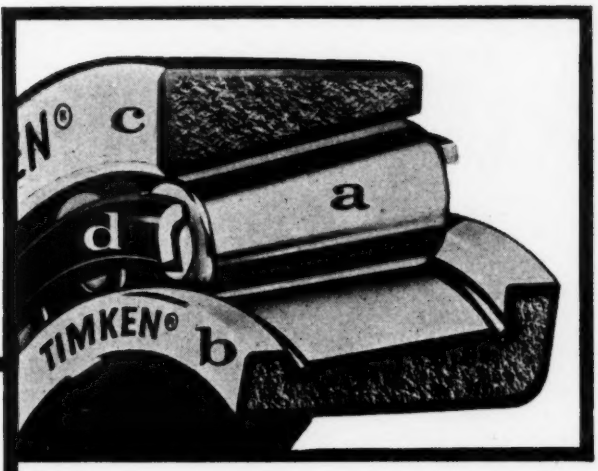
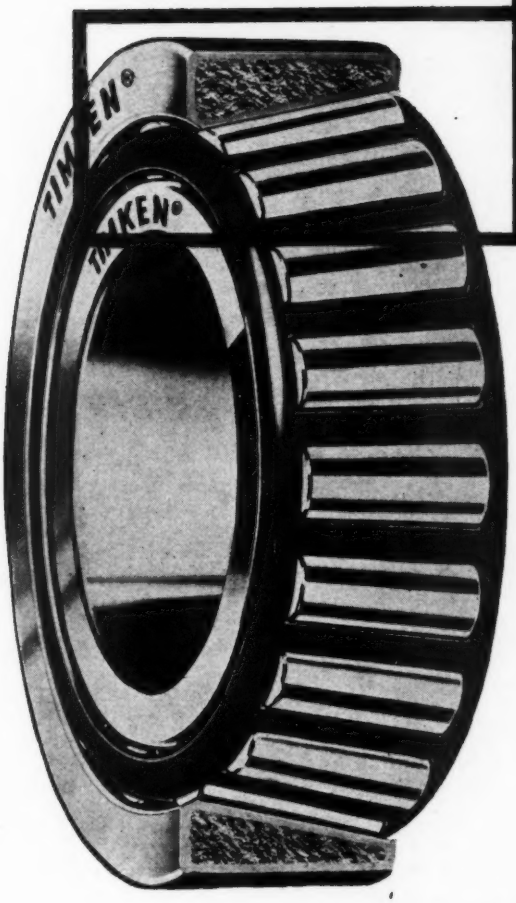
WHAT IS A TIMKEN TAPERED ROLLER BEARING?





It's a roller bearing which is tapered in design so that it can take radial and thrust loads or any combination. At the right is a cutaway view of a portion of a Timken bearing showing one of the tapered rollers (a), the inner (b), and outer (c), races and cage (d). The tapered design of Timken bearings enables them to roll the load and distribute the load along a full line of contact between rollers and races. That's why a Timken tapered roller bearing often does the work of two ordinary bearings—eliminates the need for thrust devices. And Timken bearings are geometrically designed and precision manufactured to roll true.

You'll find Timken tapered roller bearings in machines all around the world. Specify Timken bearings to get the best performance. The Timken Roller Bearing Company. Canton 6. Ohio. U.S.A. Cable: "TIMROSCO". Timken bearings manufactured in Australia, Brazil, Canada, England, France and U.S.A.

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The gas or water must be made available in the places where it will be most useful—often at a great distance from the project itself.

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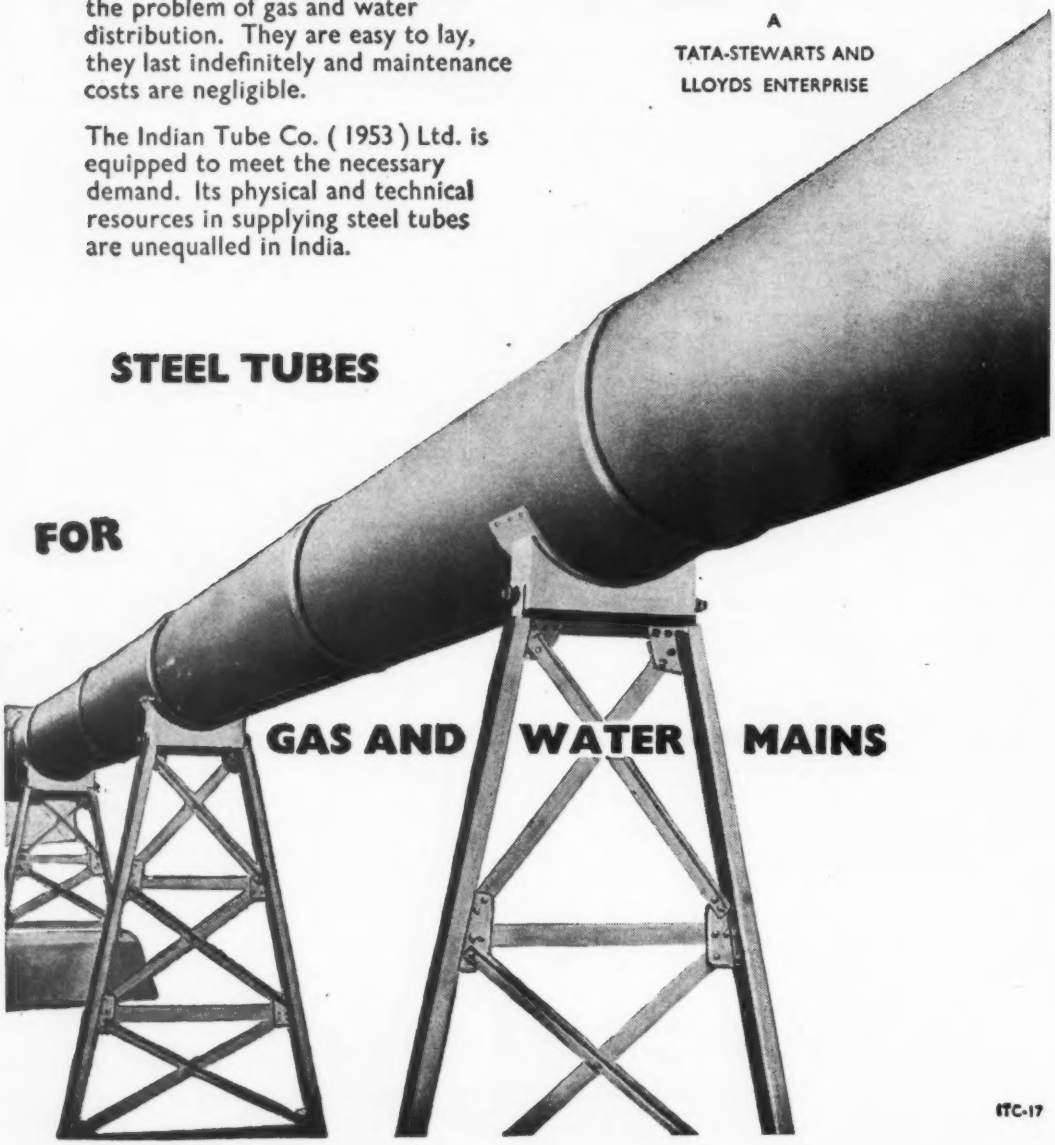

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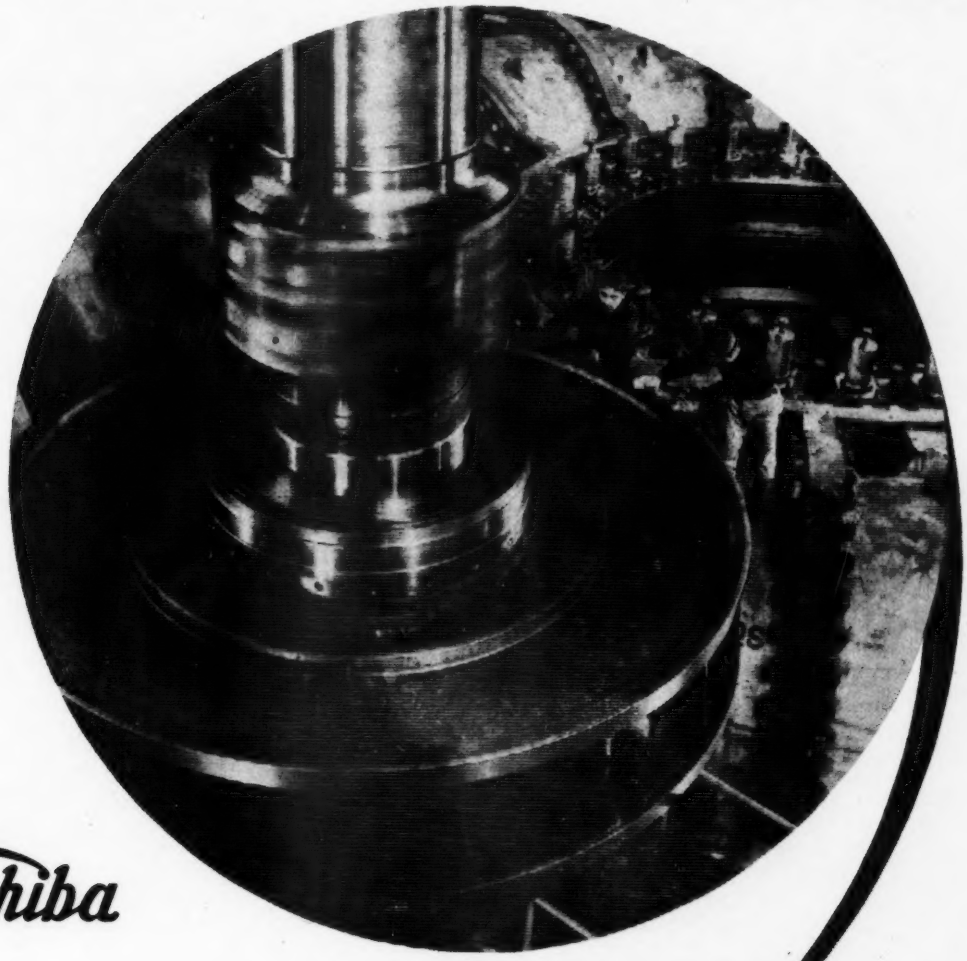
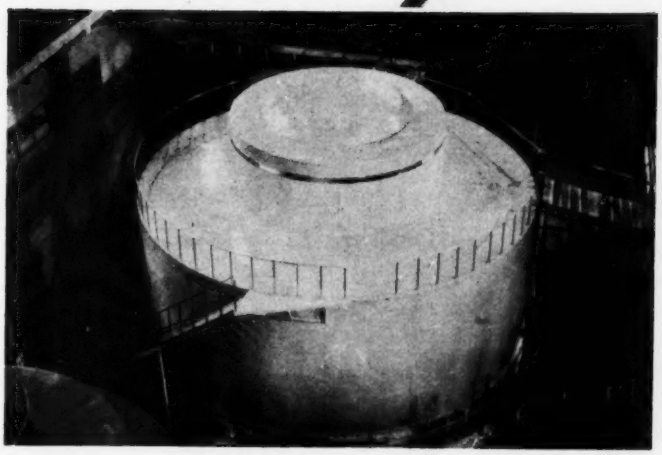


Toshiba

The generator on the right is the second largest of its type in the world. It was built by Toshiba for installation at Japan's new development project, the Okutadami Power Station. It generates 133,000 kVA and was designed big to do a big job. For information about this or any other type of equipment necessary for generating or transmitting electric power, be sure to consult Toshiba.



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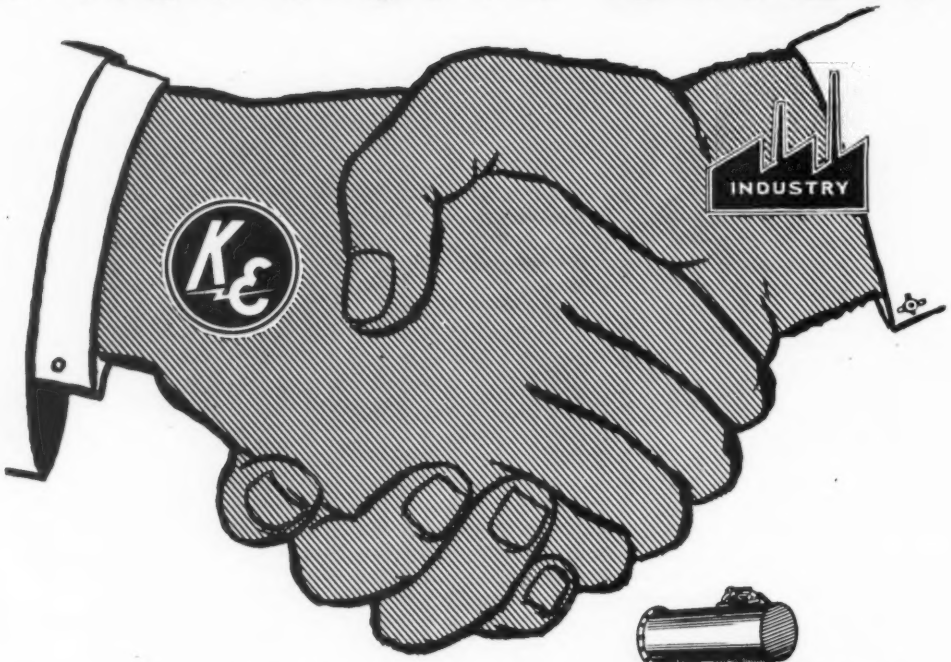

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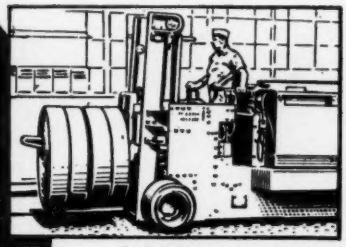
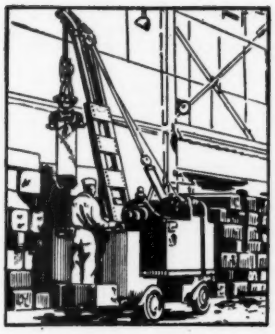
Modern mechanical handling by Battery-powered Trucks fitted with *Standard* TPg Batteries moves your goods efficiently, economically !

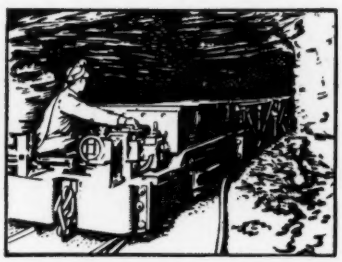


Industrial trucks are more economical, handle more goods per shift. But battery-powered industrial trucks offer a further economy: their operating costs are far lower than those of similar petrol or diesel trucks

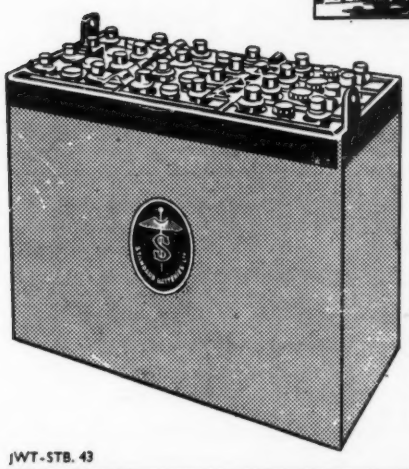
Battery-powered industrial trucks perform better than petrol or diesel types because torsion force is maximum when the truck is just starting. Draw-bar pull, too, is greater when the high-capacity STANDARD TPg Battery is used

Higher stacking—where manual handling can't easily reach—is simple with trucks. Unlike petrol and diesel types, battery-powered trucks are *noiseless*, and don't involve sparking; hence no risk of fire





Battery-powered industrial trucks—of various types for warehouses, factories, mines, etc.—carry goods safely, help avoid costly damage. They bring down day-to-day handling costs, help reduce risks involving workmen's compensation



All-round saving on battery costs

Compared to ordinary batteries for industrial trucks, STANDARD TPg Traction Batteries offer a higher capacity-to-weight ratio, an increased service life up to 100% longer, and a saving of up to 10% in battery costs. Change to modern mechanical handling methods: and fit your industrial trucks with STANDARD TPg Batteries. Write today for more information!

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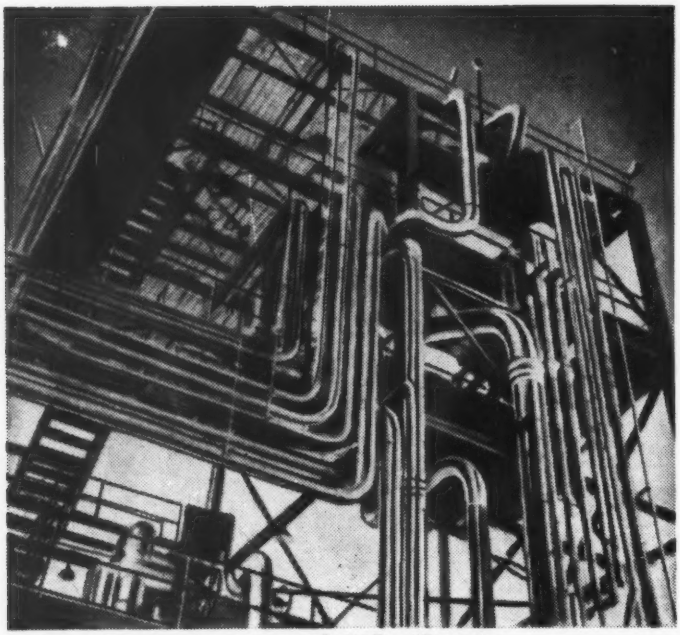

General view of pipework outside the turbine room at Trombay Thermal Power station

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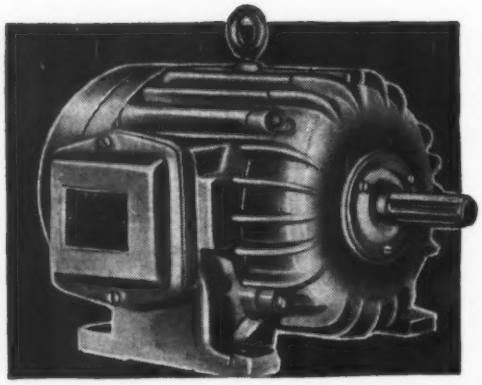

Manufactured in our PAHARPUR Works, these motors are dustproof. That's why they are particularly suited for service in places where dust and dirt are prevalent — in mills, gas works, chemical works, collieries, quarries, cement works, etc.

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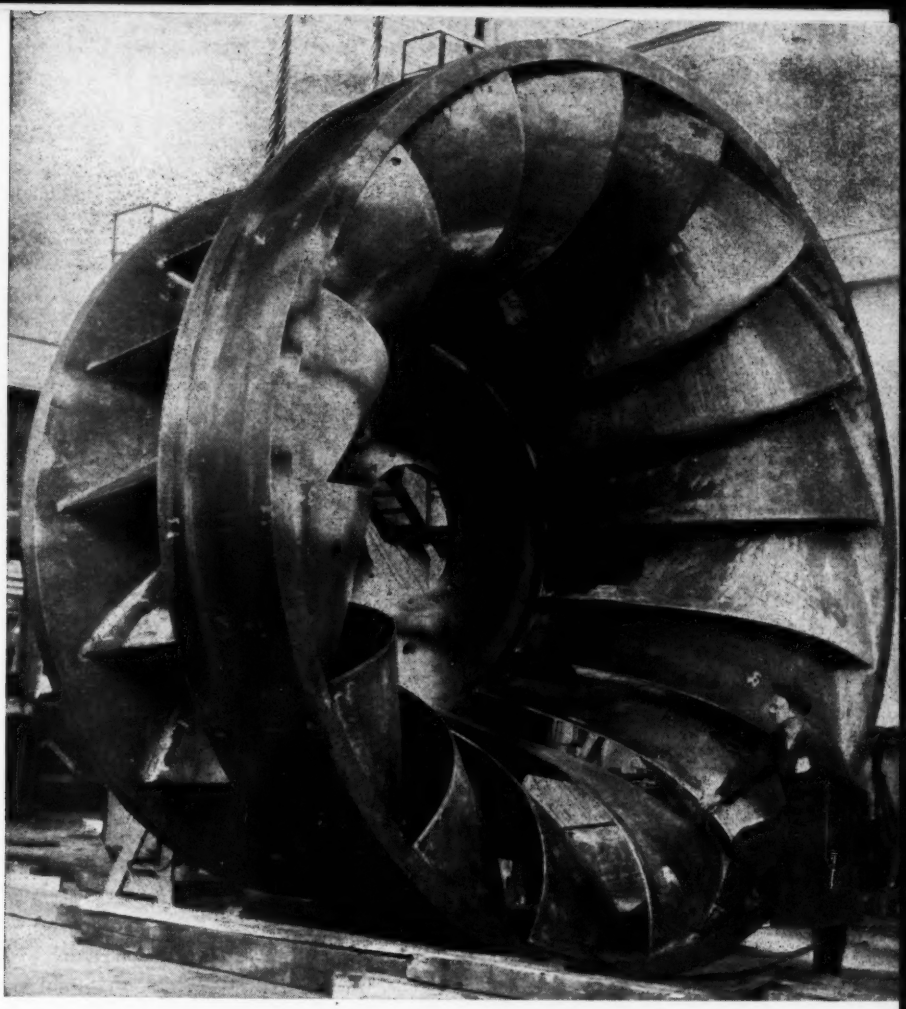
ax. guar. output 200.000 HP per turbine



NOHAB — since more than 100 years a large deliverer of water turbines — is today one of the leading turbine manufacturers in the world. The picture shows the runner for The STORNORRFORS Power Station, Sweden. In keen competition on the international market, the company has been favoured with important orders. PANCHET HILL, India, FURNAS, Brazil and BAYGORRIA, Uruguay are some examples of this. You can contact NOHAB both regarding water power and atomic power projects.

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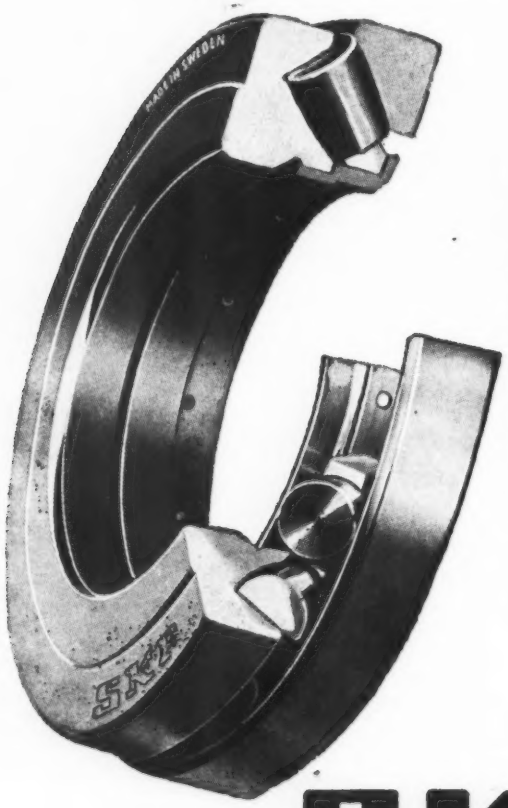

Illustrated here is the **SKF** SPHERICAL ROLLER THRUST BEARING which has one row of obliquely disposed rollers guided by a high flange on the shaft washer and running on a sphered track on the housing washer. It combines very high carrying capacity with complete self-alignment. The surface of the roller end next to the guiding flange is so formed that the rollers are always separated from the flange by an oil film when under load. The bearing can therefore be used at relatively high speeds, even if the load is very heavy. Unlike other thrust bearings, it can also carry radial loads.

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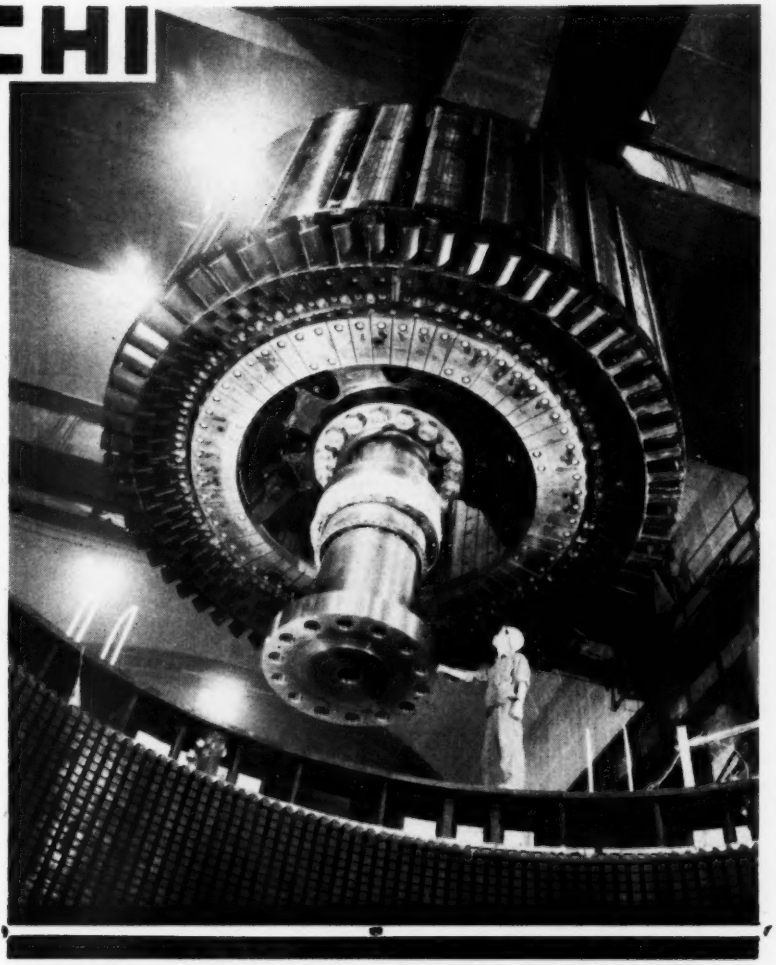

Hitachi has recently completed two 137,500 kw/125,000 kVA hydraulic turbines and generators for the Miboro Power Station in Central Japan. The turbine is of the vertical-shaft Francis type, and specified for a speed of 225 rpm, a maximum effective head of 200 m and 76.6 cu.m/sec water flow, making it one of the largest units of its kind in the world. Its runner has a maximum diameter of 3.7 m and the main shaft a diameter of 95 cm. The spiral casing, which was constructed in 13 sections to facilitate transportation to the site, has an inlet diameter of 3.35 m and an outer diameter of 11.2 m.

The generator presents a high-torsoed appearance, having been so designed in consideration of the comparatively high speed. Since the generator was designed for a rated voltage of 16,500 volts and, in this respect, represents the first such attempt in Japan, particular care was taken in the corona-shielding and impulse resistance of the stator winding. The generator is rated at 60 cycles, 225 rpm and 0.9 power factor but is also capable of operating at 50 cycles, 187.5 rpm and 1.0 power factor.

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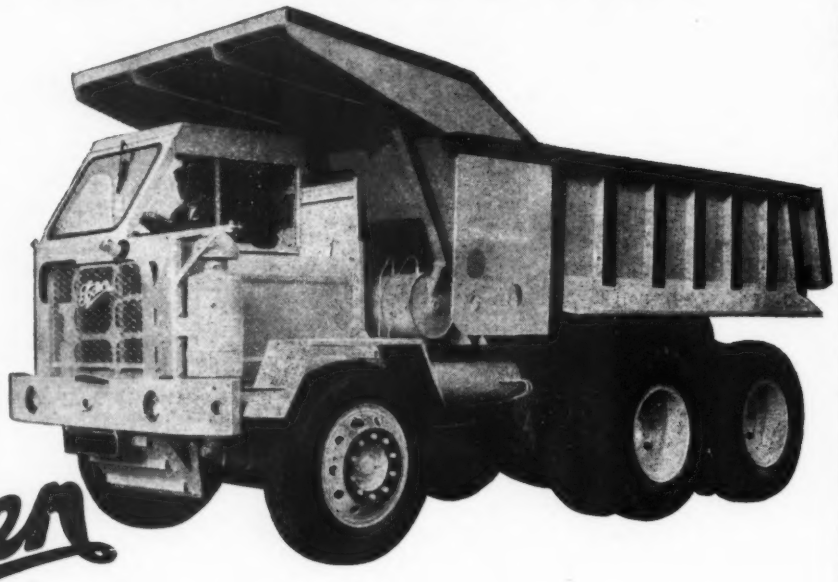

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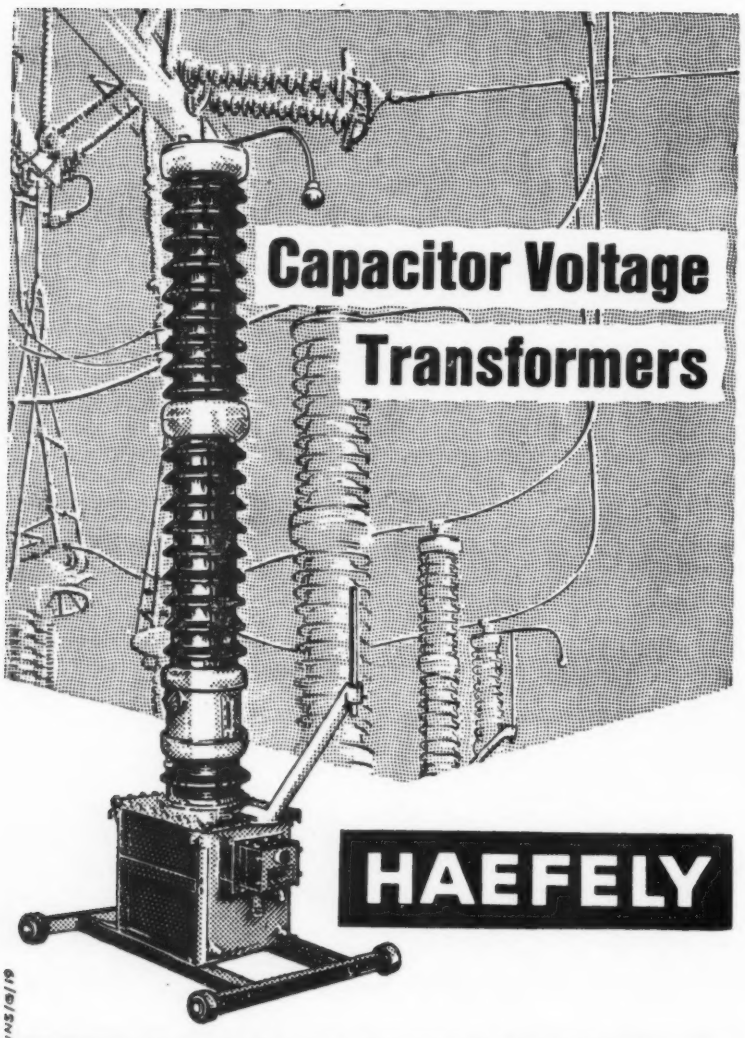

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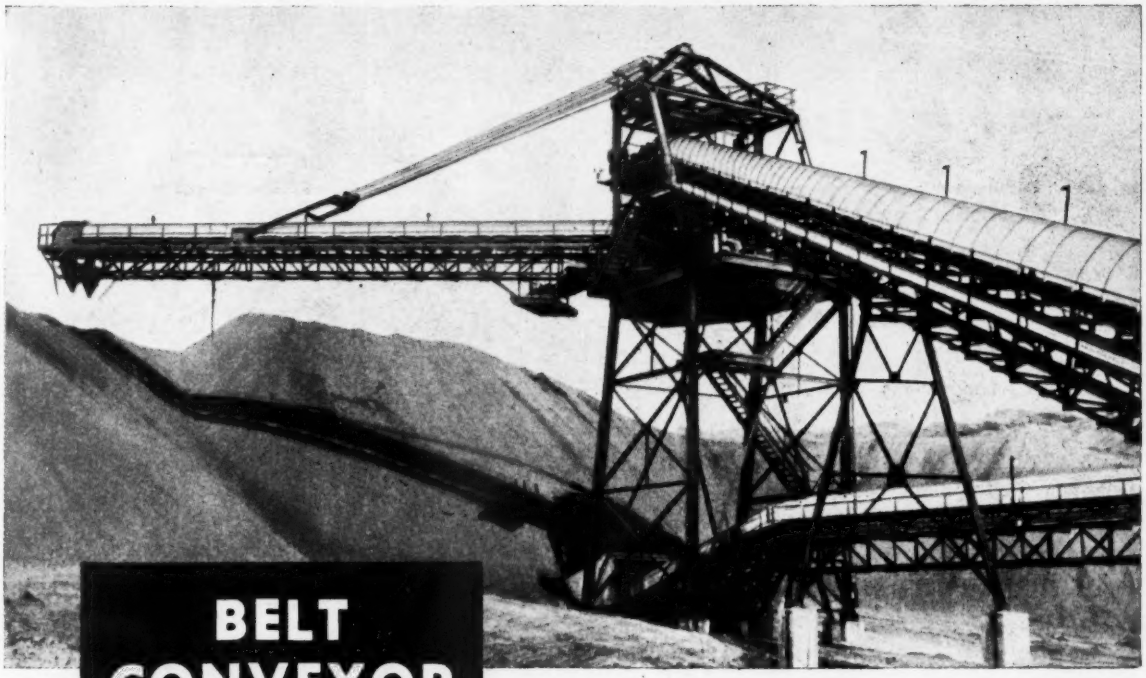

BELT CONVEYOR SYSTEMS handle coal at lower cost per ton

Shrewd power plant operators are aware of the importance of handling coal at the lowest cost per ton to attain maximum efficiency in the conversion of coal to kilowatts. The biggest single factor in reducing coal handling costs is the belt conveyor system carrying the load. It further follows that the rate of efficiency attained by any belt conveyor is dependent upon the quality construction and design features of the components under the belt.

S-A ENGINEERED PRODUCTS FOR COAL HANDLING SYSTEMS

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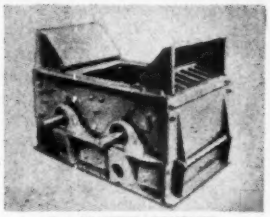

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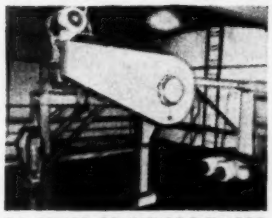

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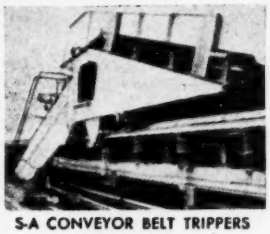

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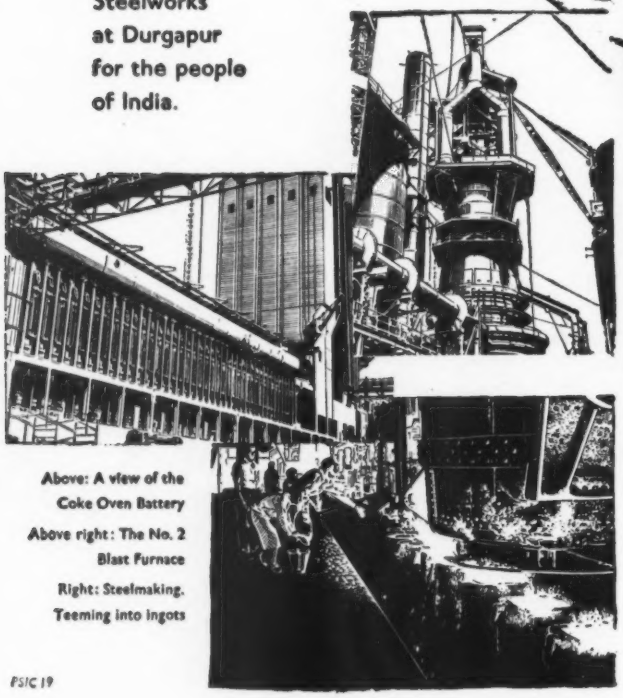

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Right: Steelmaking. Teeming into ingots

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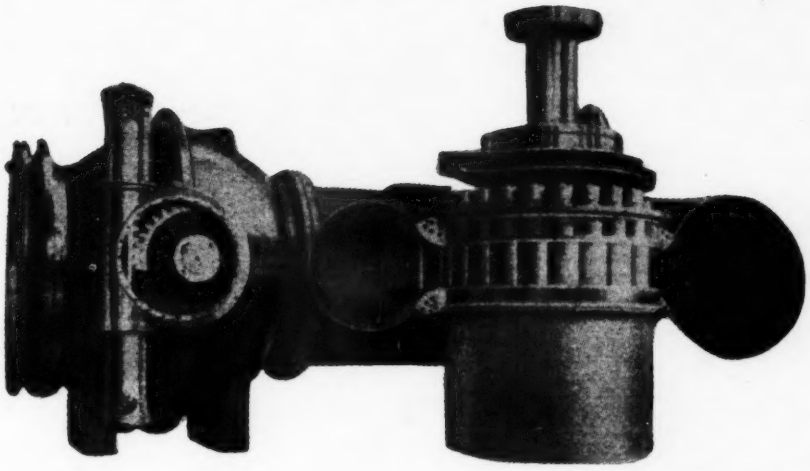

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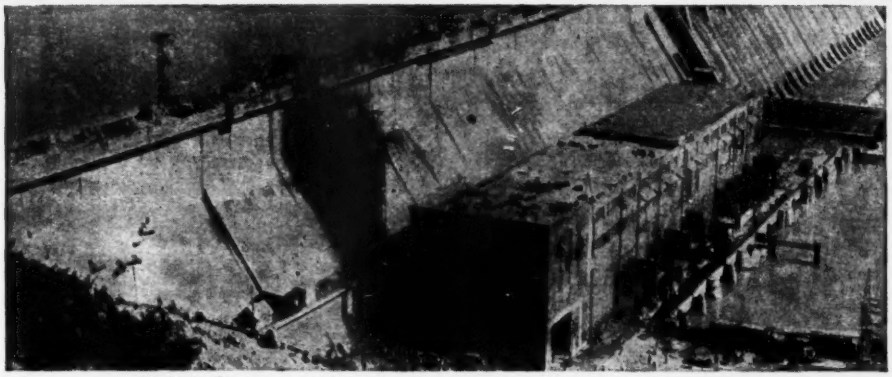

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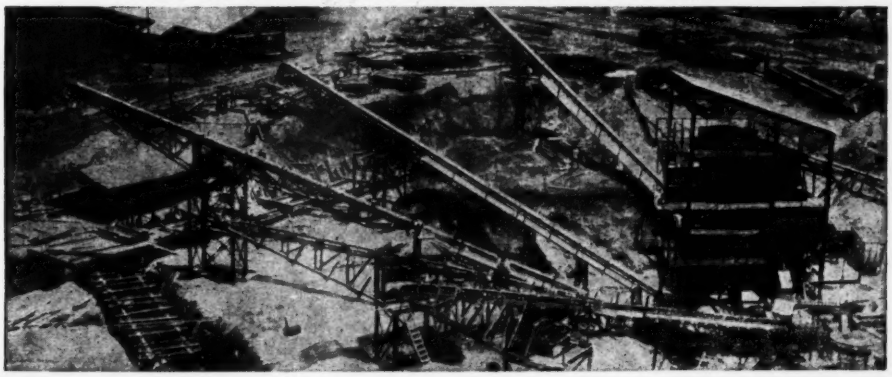

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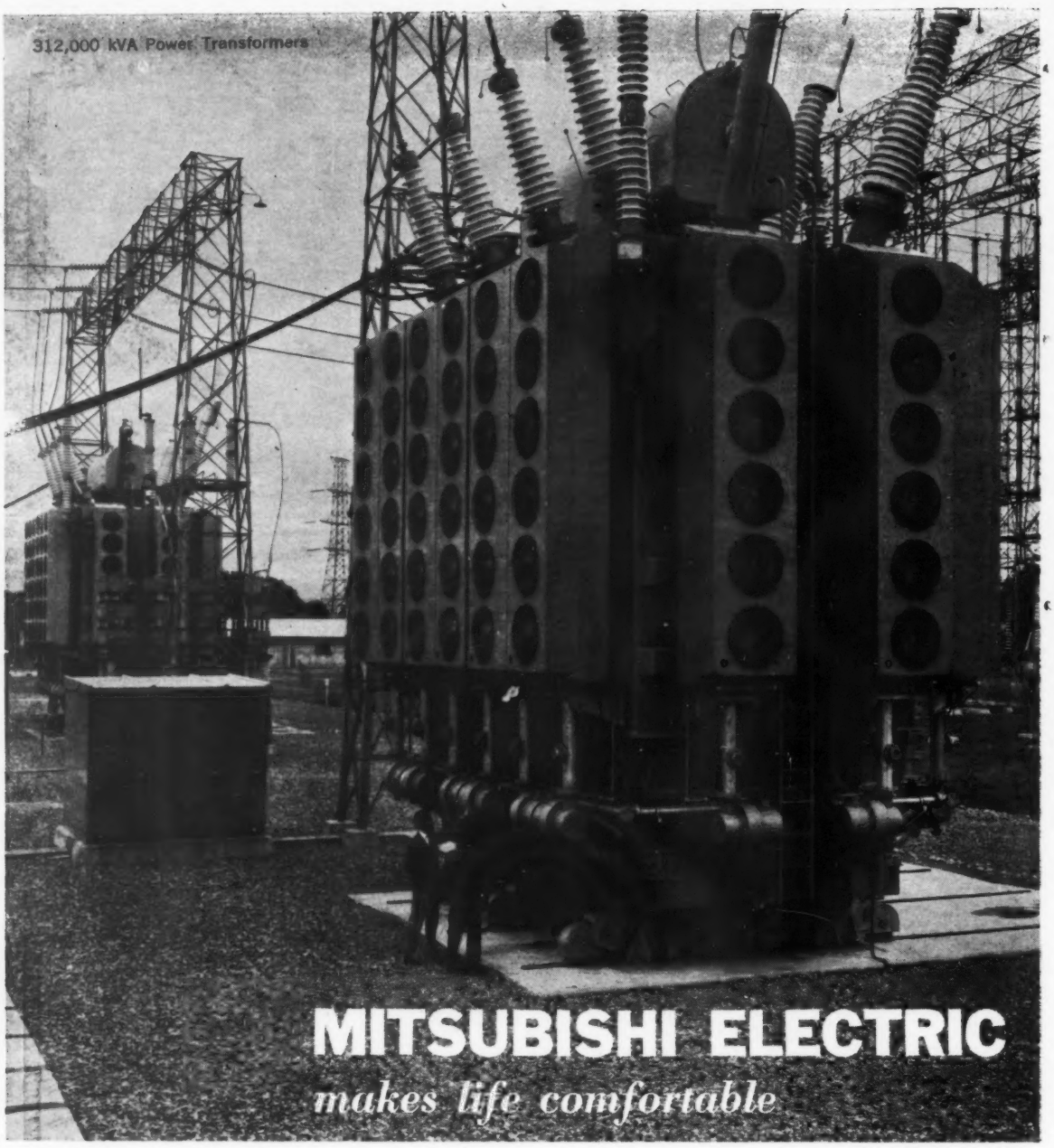

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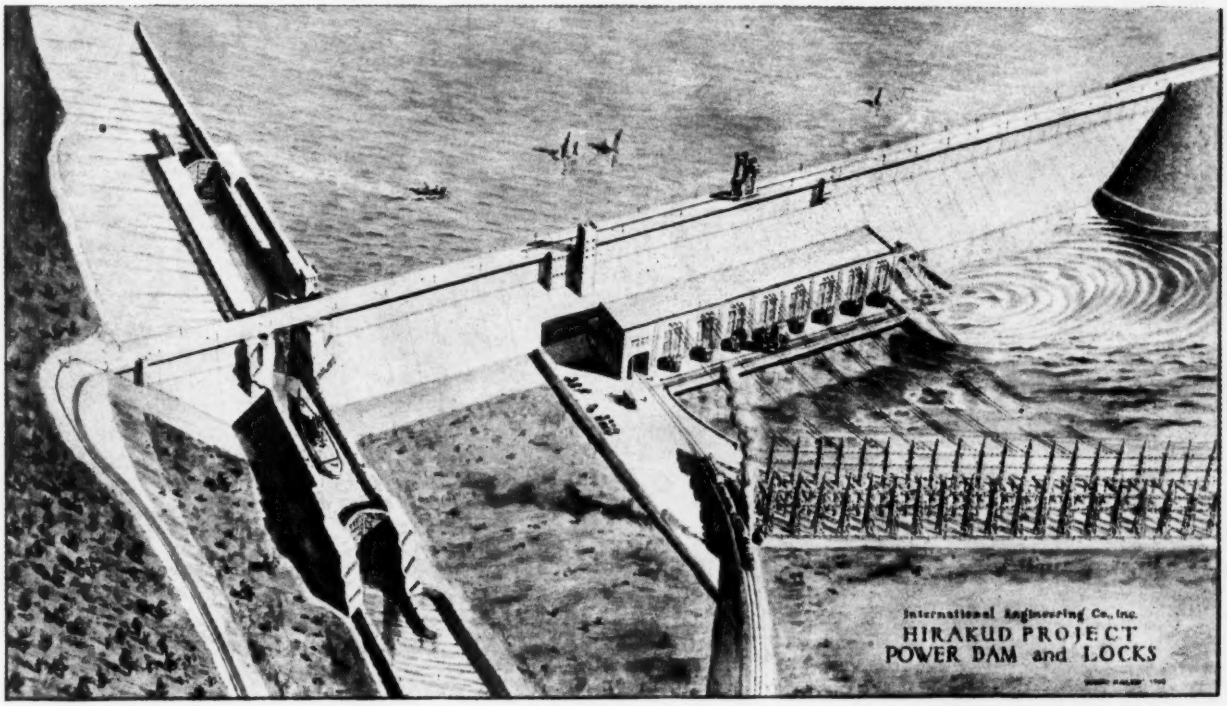

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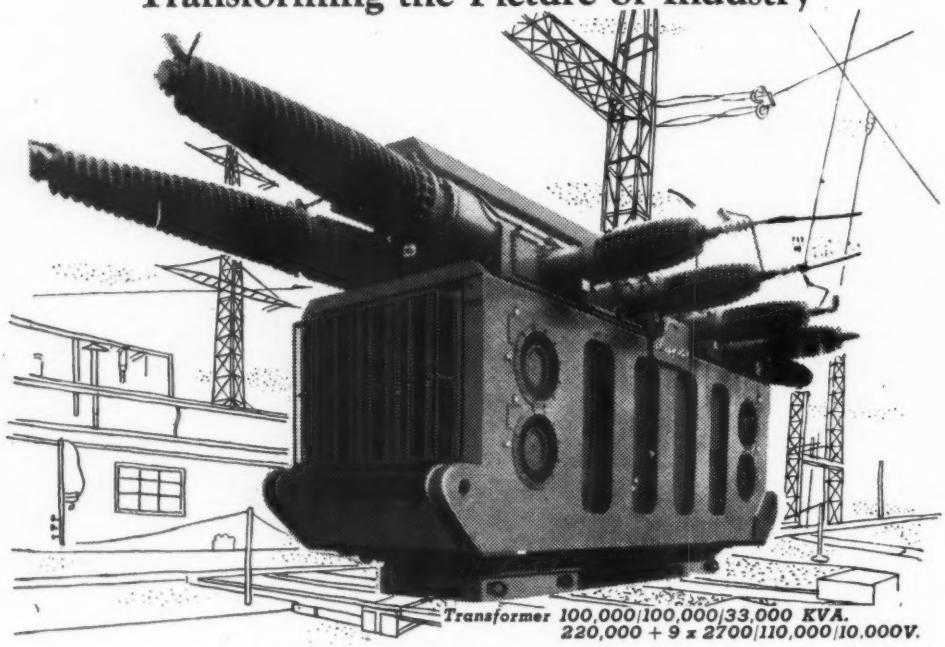

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Tenth Anniversary Number

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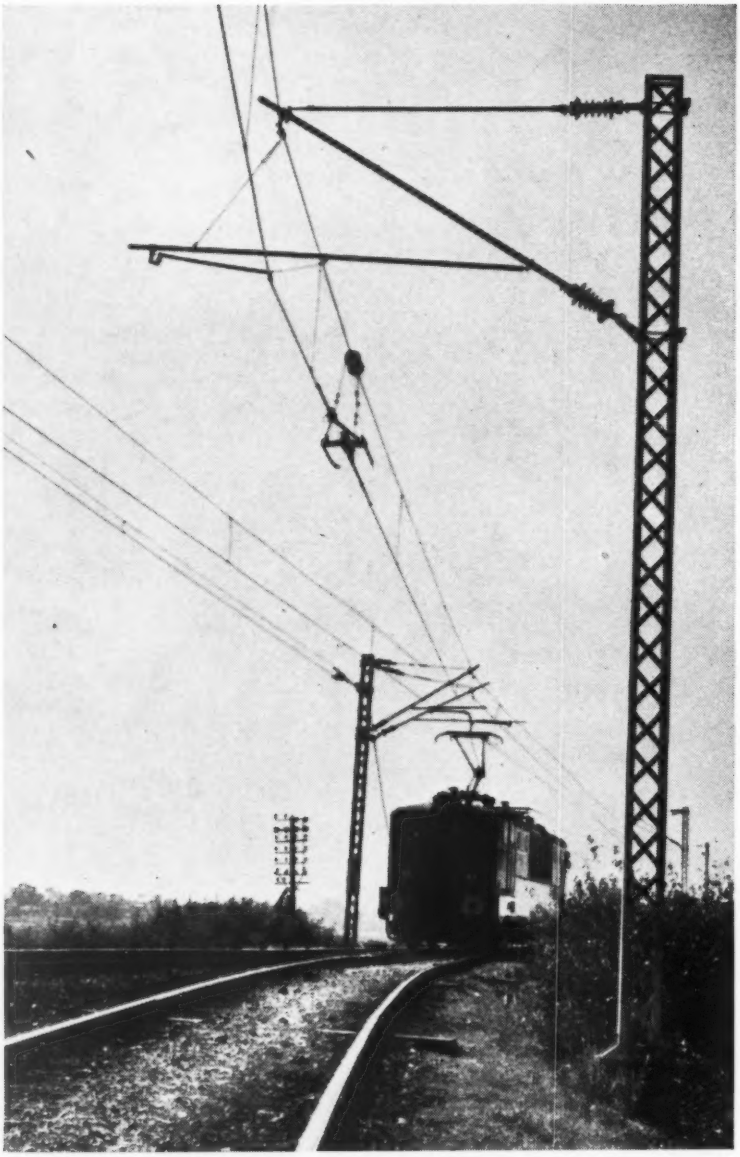

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TEN YEARS

With this issue we complete ten years of existence of this journal. It was started in a modest manner by two comparatively inexperienced journalists who thought it was time for India to have more technical reviews. Whether such an enterprise has proved useful to engineers and other specialists, planners and administrators, it is for them to say. This special issue gives some indication of the place it has occupied in the country and abroad. We on our part feel extremely gratified at the genuine response and hearty co-operation we have received from leading engineers and institutions in the country at all levels and from abroad. In fact, without such encouragement from them we could not have carried on all these years. We pledge to them and to all concerned that we shall continue to produce this journal with all our devotion and loyalty—loyalty to the cause of resource development in general and to river valley development in particular.

This issue speaks for itself. The opening contribution, significantly enough, puts in perspective the new stage that the "development" movement has attained in the world today. The modern world of specialists can develop fast indeed only when there is increasing understanding and collaboration between them; for the very word "development" implies a totality of this co-operative endeavour. With this basic idea, we leave the reader in the company of some of the most eminent engineers today as they peruse this issue.

As we turned over the different suggestions for the celebration of our tenth anniversary, we felt that we should do something that would be far from being commercial and stereotyped. We, therefore, are sponsoring, in association with the Jadavpur University and the Institution of Engineers (India), Bengal Centre, a Seminar on Engineering Education in Eastern India, and another on Power Development in Eastern India, in association with the Engineers' Circle. We felt that in these practical ways we will be helpful in promoting the cause of development in the community in which we live and on whose goodwill we flourish. In course of time we propose to publish the reports of the Seminars.

As we turn on to the coming years ahead, we look forward to a greater opportunity to serve the cause that is dear to us, with the blessings and encouragement of engineers and other partners in development from all over the world.

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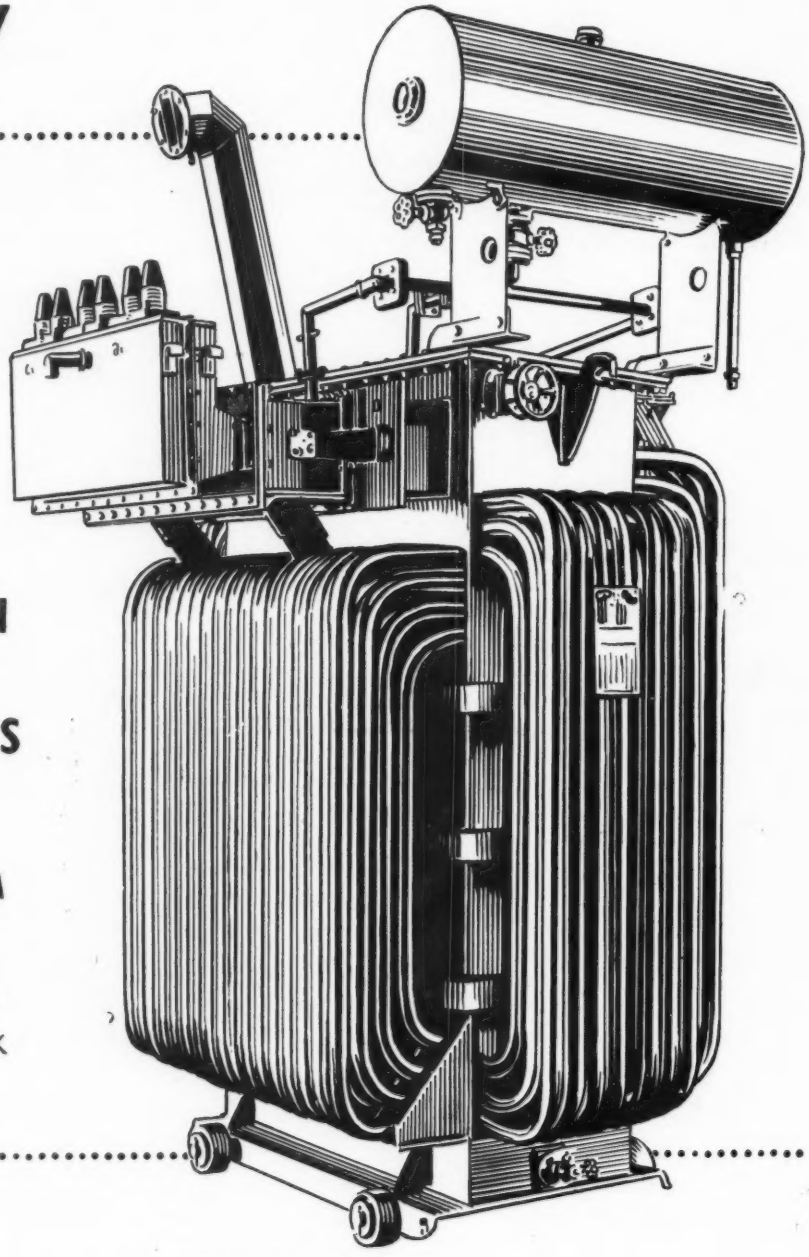

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Eugene R. Black
President World Bank

The Banker, the Engineer and Development

THE BANKER AND THE ENGINEER HAVE ALWAYS depended on one another. But the dependence has not always been a very comfortable one for either party. To the banker, the engineer sometimes appears all too eager to cut up the countryside and build fancy monuments to his imagination without any really good idea of the usefulness of those monuments. To the engineer, the banker sometimes seem a cold and remote figure, sitting on top of a mountain of money from which he is parted only after a tedious and mysterious ritual of justification.

While these are stubborn stereotypes, in one field, anyway, they are giving way to a new kind of dependence, based on greater mutual respect and understanding. That field is the field of international development in the so-called underdeveloped countries of the world. Here the bankers are beginning to scout the land alongside the engineer. Here the engineer is beginning to accept the bankers' procedures of economic and financial analysis as a useful guide in deciding just where to start in the business of reshaping the countryside.

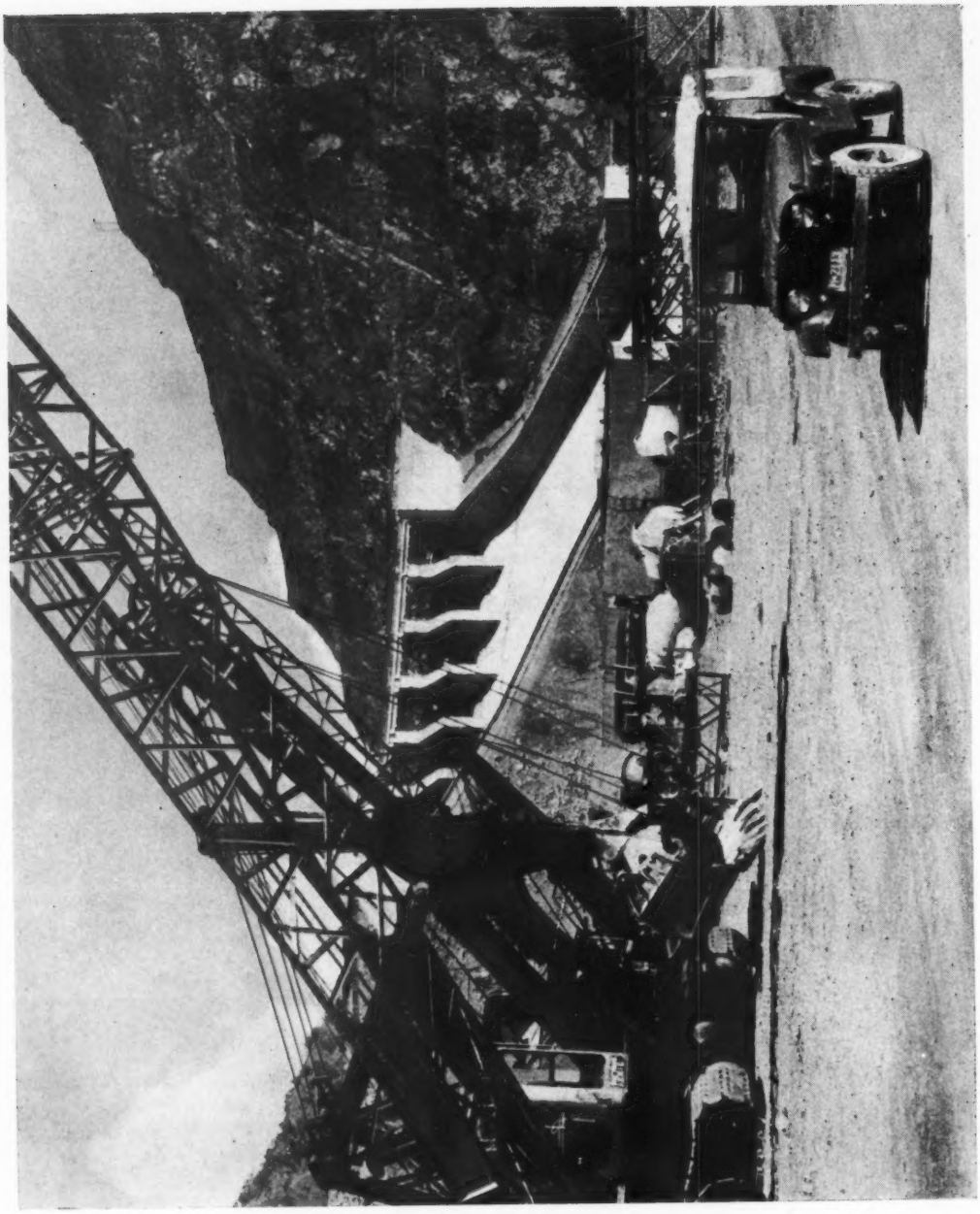
In the World Bank we have had considerable experience with bankers and engineers working in harness. We have our own staff of some 280 professional men and women who over the years have developed hundreds of working partnerships with bankers and engineers in our 68 member countries. While it would be too much to say that we have been able to agree on any hard and fast set of rules about how to plan and carry out development projects, it can be said that an area of agreement on procedure has been staked out. This accomplishment deserves a little elaboration. I think, because in it lies considerable hope for the future. The more agreement there is about how to escape from poverty in the underdeveloped countries today, the more substance there will be to our common hopes for greater tolerance and mutual respect among nations and races.

When we get a project in the World Bank, we immediately form a team of bankers, engineers and other specialists within our own staff. Each member of the team views the project from a different point. One will ask, "Will the goods or services which the project is expected to produce meet a need important to the development of the river valley?" This man has what you might call an economic point of view. Other members of the team will want to know if the project is well-designed and planned; one will ask the question from the technical viewpoint; another from the point of view of management and organization; still another will want to know what plans have been made to buy the materials needed to build the project and what arrangements have been made for supplying the raw materials, power and labour needed to operate the project. And one member of the team will look at the project from the financial viewpoint, asking whether the proposed method of financing is appropriate and whether the expected financial returns are adequate to justify the investment.

Now, assuming that the borrowing country is in a position to service a development loan, these teams of experts, in company with their counterparts in the country concerned, are charged with coming up with an agreed judgment about whether a project is justified. Obviously here is an acid test of the ability of bankers and engineers to work in harness, for the various points of view which have to be canvassed invite long debate. What is good from the technical point of view may give the economist shudders and the management consultant nightmares; what constitutes sound finance may make the engineer feel he is in a straightjacket.

George Bernard Shaw once said of economists that if you laid them all end to end they would never come to a conclusion. Such might appear at first glance to be the case when a group of bankers and engineers get to appraising a development project.

Yet, in fact, over the past 14 years the World Bank and its borrowers have managed to come to agreement over some 600 different development projects in 53 countries and territories among our membership. And a veritable mountain of money has been involved—more than $5,000 million from the Bank itself and easily that much again in the form of investments in these projects by the borrowers themselves. (The Bank as a matter of policy never finances more than a portion of the cost of a given project, usually that portion which represents imported equipment, material and services; the borrower normally has to cover all local costs himself.)



Binga Hydro-Electric Project, Philippines.

Lunersee Hydroelectric Project, Austria.

KESC Thermal Plant, Karachi, Pakistan.

Furnas Hydro Project, Brazil.

The system has worked because the bankers concerned have become something more than bankers, and the engineers, something more than engineers. All have become what you might call development-minded. The bankers realize that financial resources are only one of the tools necessary for successful development, and the engineers realize that the business of making the properties of matter and the sources of energy in nature useful to man is as much an art as it is a science.

For example, the good development engineer today has a working knowledge of practical economics. He is aware that in the underdeveloped countries today Governments are trying to use modern science and technology to bring about changes in the economic environment more rapidly than has ever been done before. And these engineers know that when man sets out to reorganize nature in one fell swoop, he must be a very cautious calculator; too much is at stake to do otherwise, too much scarce capital and too many individual destinies.

So the development engineer has come to accept the need for various economic tests of his ideas. Perhaps it is a market survey to determine whether the market for the power output of a big hydroelectric dam does actually exist or is in prospect. (For every dollar invested in such power facilities, something like twelve dollars of capital must be invested in industries and other facilities which will use the power.) Costs and benefits must always be compared. This may involve weighing the advantages of a big, multi-purpose power dam, serving agriculture and industry, with smaller, separate facilities such as an irrigation barrage and a thermal power station. It may involve deciding whether at some given time an investment in an industrial plant will give more leverage for development than a smiliar investment in a basic service. The engineer's special knowledge does not provide sufficient evidence on which to base a conclusion. But neither can a good conclusion be reached without his evidence.

The good development banker today has a healthy respect for the technical genius and versatility of the engineer, and is aware that engineering developments may affect his own business, as has already happened in the field of electric power financing, for instance, as a result of atomic engineering. The World Bank itself recently had a hand in an elaborate study of the commercial prospects of an atomic power plant near Naples in Italy, and construction of this plant has now begun. A by-product of the exercise was almost as important, from this experience the Bank's development economists are in a much better position to determine the economic circumstances in which the the application of atomic technology may benefit power development in the under-developed world.

In approaching a given project, the development banker and the development engineer alike must both be keenly aware of what might be called the human problem—the problem of organization and management. The shortage of management experience and ability is easily the most difficult obstacle in the way of economic growth in most underdeveloped countries. It is difficult because, unlike capital or technical knowledge, it cannot be bought wholesale anywhere in the world. It is difficult because the formulas for good management in an industrial society sometimes have to be revised extensively for use in an underdeveloped country.

A good part of the problem of promoting more rapid development in an underdeveloped country involves promoting a greater awareness of the role of

Kariba Dam, Southern Rhodesia.

Constructing Access Roads in side of cuff—Dez multi-purpose project, Iran.

Tokke Hydro Project, Norway.

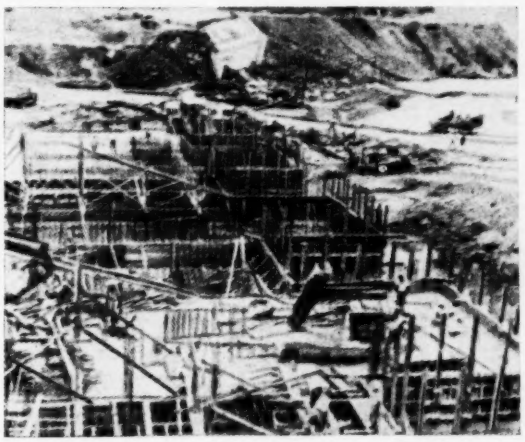
Yanhee Multi-purpose Project, Thailand.

management. Much more is involved than just operational efficiency. It benefits little if the new power dam can generate large quantities of electricity but operates at only a fraction of its capacity because insufficient attention has been paid to finding customers. Marketing is a function of management. And so is planning for the future. This involves developing people as well as physical plans. Good management today involves good training, good labour relations and good community relations. Perhaps most important it involves encouraging upward mobility within the ranks of a factory or utility organization, that is, the creation of opportunities for able men and women to get ahead on their merits whatever their background may happen to be. The development-minded banker and engineer may not have any formulas for bringing about an awareness of the importance of management in the large, but they know that they cannot succeed in the absence of such an awareness.

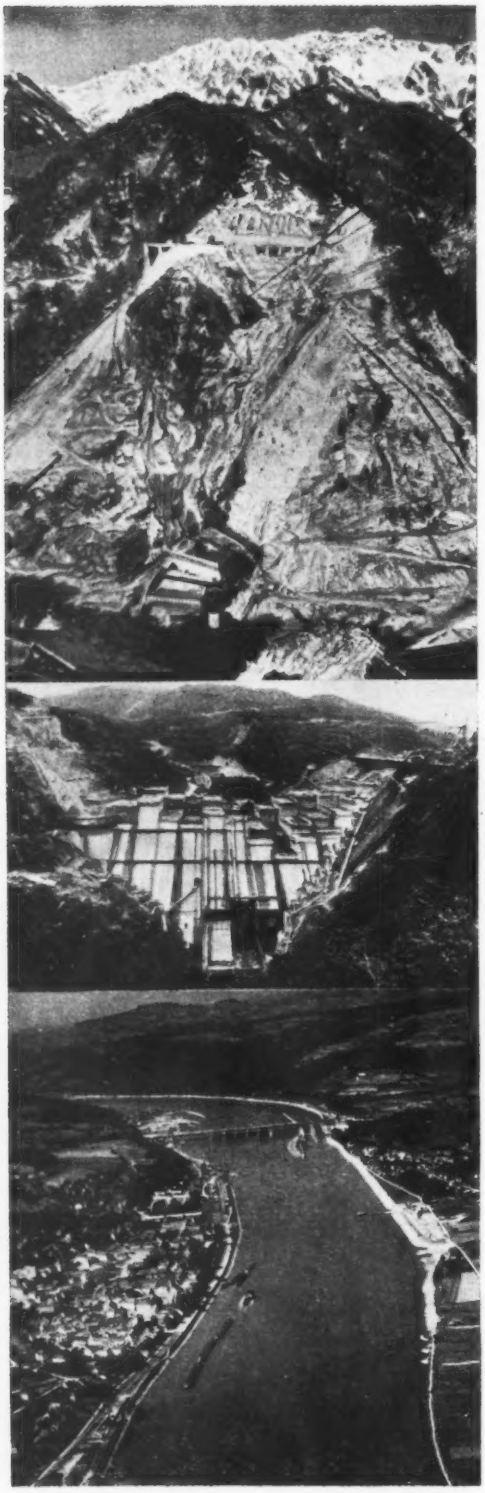
A proper concern for efficient administrative and financial organization can contribute materially to overcoming the shortage of management experience in an underdeveloped country. It is another indispensable part of development engineering. If a development project is organized from the start in such a way that information to and from management and the various operating parts for the project flows quickly and intelligibly, the management's problem is greatly eased. Then top management is not only always in possession of the essential facts and figures on which it must base its decisions; it is also encouraged to delegate authority to operating departments in order to free itself to concentrate on the broader decisions of policy and operations which should be its major concern.

Certainly no less important is sound financial organization. And this means more than keeping accurate books and issuing informative and up-to-date reports. It means among other things providing finance for future expansion. In an underdeveloped country this is particularly important; hardly any such country today has a functioning local capital market capable of financing large industrial and utility enterprises. That means either the Government must provide finance, or the enterprise itself must set aside revenue for future expansion out of its own earnings. In the case of public utilities, particularly power plants, this latter course is almost always preferable. It is not too much to say that the power company which cannot set aside out of its own revenues something towards its own expansion—something over and above operating costs, maintenance costs and service on its debt—is a power company headed for trouble. For when the demand for electricity exceeds the supply of that plant, as it surely will if development succeeds, then management will have to go to Government and compete with all the other claimants on the Government's resources for the money to meet the new need.

These are just some of the points of view which we canvass in the World Bank before deciding on the



Mazalepei Hydroelectric Project. Foundations of the power house of the Apules hydroelectric plant in Puebla. Capacity of plant: 156,000 kilowatts.



merits of a development project. But, more to the point, these points of view are part of the professional outlook of an ever-growing army of development engineers and bankers throughout the underdeveloped world. You might say there is a growing lack of controversy about them, or conversely, a growing area of agreement around them.

This new and growing alliance between bankers and engineers has not made the world safe for development by any means. Neither bankers nor engineers can tell a nation how it ought to allocate its resources among the competing and conflicting demands which exist in all societies and among which economic demands are only one kind. There is, at any given time in any given country, a conflict between the demands of growth and the demands of national security; between the demands of growth and the demands of equality and welfare; between the demands of growth and the demands of cultural development. Neither the banker nor the engineer can settle these conflicts; in fact, they never can be settled once and for all. They must be reconciled by the rulers of society either through the give and take of the democratic processes or through the repressive paraphernalia of the totalitarian state.

What the banker and the engineer can do—and must do in the name of development—is to place in perspective, shed light on and illuminate the choices before these rulers as they affect the economic future of their countries. The more professional men and women concerned with economic growth work together in harness and broaden the area of agreement among themselves, the more their evidence is bound to affect the big decisions in the underdeveloped countries. And can we not say that these big decisions are bound to be better decisions in terms of the peace of the world if they are taken with an awareness of the economic facts?

The growing alliance between the banker and the engineer holds out the hope that more and more nations will turn toward engineering as an escape from poverty in the underdeveloped world and away from destructive rivalries and mutual recrimination. This alliance has within it the power to mobilize science and technology to preserve the balance of hope in a future that is compatible with a respect for individual freedom and with tolerance among nations and races.

(Top) Kurobe Gorge Hydro Project, Japan.
(Middle) Arimene Hydro-electric Project, Japan.
(Bottom) YBBS—Persenberg Run-of-the-river Dam across the Danube, Austria.

V. T. Krishnamachari
Formerly Dy. Chairman
Planning Commission, India

Irrigation Policy in India's Plans

AMONG THE MOST IMPORTANT PROGRAMMES INCLUded in our Five-Year Plans are those intended for utilising the water resources of the country for irrigation, generation of hydro-electric power, navigation and other purposes. Taking irrigation alone, it will be correct to say that few countries have undertaken and carried out, in a comparable period, programmes of the magnitude embodied in our Five-Year Plans. The following figures will give an idea of the size of these programmes. When planning commenced in India (1950-51), the area irrigated from large and medium sources was 22 million acres. The 'book value' of the sources was about Rs. 110 crores. The estimated cost of large and medium irrigation schemes included in the first two Plans is about Rs. 1,400 crores. When completed, these are expected to irrigate 38 million acres. By the end of the Second Five-Year Plan an expenditure of Rs. 770 crores will have been incurred on these works creating an additional irrigation potential (defined in the Draft Outline as the area which can be irrigated with the water made available at channel outlets) of 14 million acres. This includes Rs. 80 crores expended on these projects before the commencement of the Plan. In the Third Plan Rs. 650 crores are proposed to be allocated for irrigation. In the aggregate, therefore, about Rs. 1,400 crores will have been spent on irrigation projects by the end of the Third Plan. It is further envisaged that, by 1975-76, about 85 to 90 million acres in all will be under irrigation from such sources. As regards power, the total output at the end of the Second Plan is expected to be 5.8 million kW of which 2.10 million kW will be hydro-electric involving an expenditure of Rs. 240 crores. By the end of the Third Plan, there will be generated 11.80 million kW of which 4.75 million kW will be hydro-electric power costing about Rs. 510 crores. These figures give an idea of the scale on which river valley development is proceeding under the Plans.

It is obvious that expenditures of the order indicated cannot continue to be incurred unless steps are taken to ensure that maximum results are secured by way of increased production and additions to revenue from expenditures already incurred. No under-developed country can afford to wait indefinitely for returns on its investments. The Finance Commission of 1957 has drawn attention to the fact that irrigation projects in States do not yield commercial returns and that, year after year, the deficit in their working is increasing. In other words, the States give annual grants for the maintenance of these works from their exiguous revenue accounts. This is in spite of the fact that, in regard to the large multi-purpose projects under construction, interest is automatically added to capital and is not borne at present by the Revenue Accounts. There is also a much wider and more important aspect in regard to irrigation projects with which this paper is concerned. No plans for large-scale social and economic development can be carried out unless agricultural production increases rapidly enough not only to meet the increasing internal demands but also to build up exports. This is the justification for the scale of allocations to irrigation projects. The question, therefore arises—what steps should State Governments take to ensure that the irrigation projects are implemented in such a manner that, at every stage, the maximum results are achieved in agricultural production and a diversified agricultural economy is built up rapidly? The issue may be stated in a different way. It is obvious that, to carry out so many large and medium projects in different parts of the country with the requisite speed, efficiency and sense of urgency in regard to results, there should be revolutionary changes in outlooks, techniques and moods. What are these changes and how can they be brought about? This article seeks to answer this question in broad terms in the light of the experience gained in the last ten years.

For the sake of clearness, the points proposed to be made may be grouped under the following heads:

I. The Project Authority — Composition and functions.

II. Planning of the project.

III. Implementation including maximisation of production.

IV. Financial aspects.

I : The Project Authority

The establishment of a Project Authority for very large projects—inter-State projects as well as projects confined to a State—is now accepted as necessary. There is no doubt that this should be extended to all projects costing, say, Rs. 5 crores and above and that the authority should be set up at a very early stage, i.e. as soon as a project is accepted in principle and before detailed planning commences. This authority has two functions. The first is to see to efficient and economic planning and implementation, unifying the activities of the different departments concerned. The second—and this should be stressed as its importance is not sufficiently recognised at present—is to bring the community for whom the project is intended fully into the planning and execution and to prepare them for the obligations they have to undertake in return for the benefits. In other words, they should be made to feel that the project is theirs and that it is for them to get the best results from it through their co-operative efforts.

The composition of the Authority should not be rigid. While conforming to certain broad principles, there should be scope for local variation. A statutory corporation on the model of the Tennessey Valley Authority was set up for the development of the Damodar Valley. This has not been adopted in regard to any other project. Doubts are felt as to whether this pattern can fit in with the constitutional requisites and other conditions in this country. There is difficulty in reconciling the autonomy of the corporation with the accountability of the Central and State Governments to Parliament and local Assemblies, for the proper conduct of its affairs. The Central Government advances loans with the sanction of Parliament and these loans are passed on to the Corporation through the budgets of State Governments. There has thus to be full accountability to Parliament and the State Assemblies. There is also another factor. Under the Constitution, the State Government has responsibility for developmental operations in every part of the State. It is not feasible in practice to isolate a specified area of the State as coming within the developmental authority of an Inter-State Corporation. To give one example, the intensive development of the million acres in West Bengal commanded by the D.V. C. canal system can be done more speedily by the West Bengal State authorities than under the Corporation. For reasons like these, the present policy is to have non-statutory bodies set up by executive orders of Government and in inter-State projects by agreement between the States concerned. These take the form of Boards of Management or Control of which the Finance Minister and the Ministers concerned with the various Development Departments are members. Official committees consisting of heads of Development Departments and Secretaries to Governments act in an advisory capacity to the Boards. Besides this, there is a close-knit executive body presided over by the Chief Administrative Officer of the project and consisting of the main technical heads of departments, which is responsible for the every-day affairs. Where there are inter-State projects or large State projects, representatives of the Central Government are also on the Board. On the whole this pattern appears to be workable. One advantage is that in the case of inter-State projects, while there is co-ordinated planning, the responsibility for carrying out programmes in each State rests with the Government concerned. The existing arrangements are, however, defective in that they are not effectively linked up with the community development agency—i.e. the district development organisation consisting of officials at all levels from the village upwards—in the areas commanded by the project. It is only through this that the people benefiting by the project can be brought into, and kept in touch continuously with, planning and execution. It should therefore be an invariable rule that the block samiti or samitis in the areas should be linked up in an organic way through the Community Development Minister on the Board and the Collector or Collectors concerned on the Executive body. Where the commanded area is large, the appointment of a Special Assistant Development Commissioner might be of value.

The 'field' organisation in the commanded area is thus a vital part of the Project Authority. The Planning Commission has always suggested that, as soon as it is known that a project is to be taken up, the area under it should be brought under one or more community development block or blocks, if it is not already under the movement. The officials and non-officials of the block samitis will explain to the people their rights and responsibilities and why they have to pay betterment contribution and water rates; will see that demonstration farms are established to accustom people to the use of irrigation and to new crop patterns; will take steps to ensure that lands are prepared for receiving irrigation when water becomes available; will get the villagers to construct the canal systems in time and also excavate and maintain field channels; and will ensure, in all ways, that the best benefits are obtained from the projects.

It should be explained that, in regard to inter-State projects, the Board of Control or Management which is set up for individual projects should be in addition to the River Boards contemplated in the River Boards Act, 1956. These River Boards serve a permanent purpose, enabling a unified view to be taken of the needs of a river system as a whole and specially of the measures needed for soil conservation and afforestation programmes, which will, among other benefits, prolong the life of irrigation works in the valley. It is to be hoped that River Boards under the Act will be set up for most inter-State rivers within as short a time as possible.

II : Planning

There are four parts in a plan for an irrigation project:

(a) construction of the dam or barrage for storing water;

(b) construction of the canal and distributary system by Government agency ending at definite and convenient points in every village;

(c) construction according to a time schedule fitting into item (b) by the beneficiaries of field channels in every village so as to irrigate every acre that can be served by the project as soon as water is available in the canals; and

(d) improvement of agricultural techniques so that by their adoption the maximum agricultural output can be secured.

The essence of planning is to ensure that all these details are worked out carefully; that these stages are synchronised and co-ordinated in such a way that there is no time-lag between them; and there are maximum benefits at every stage. This means that detailed plans and estimates are prepared carefully from the beginning, the villagers concerned being consulted on the outlets in the villages and given assistance for organising themselves to construct the canals within their villages and also to carry out their obligation to construct and maintain field channels. An irrigation project often falls into definite parts. As water is stored in the reservoir at varying levels or becomes available in the barrages, the canal system for utilising the quantities available must be complete right down to the last irrigable field, so that benefits are realised as the project proceeds. Planning should have this in view.

The Plan should also include details of the drainage arrangements needed. In the past, this has been neglected with the result that in several parts of the country lands have gone out of cultivation through defective drainage and salinity. It should be an invariable rule that a drainage system should be an integral part of every irrigation project.

Afforestation and soil conservation in the catchment areas of reservoirs should also be carefully considered at the planning stage and proposals worked out. Where special measures are necessary over and above the ordinary conservation programmes, loans would be justifiable from the project funds. When the catchment area lies in a State different from the State or States which benefit by irrigation, the latter State or States should pay a contribution to the State in which the catchment area lies, for programmes of conservation. This would be a legitimate charge on the project funds for a certain number of years.

A network of demonstration farms for training agriculturists in the use of water and evolving new crop patterns and techniques should also form part of the plan for every project. Such services are ordinarily a responsibility of the community development agency, but in the larger projects the expenditures needed would be heavy and loans may be suitably given from the project funds for this purpose.

The State Government should also have detailed programmes for the development of the commanded area by the construction of roads, establishment of regulated markets, etc. These should be prepared by block samities with the help of the people in the locality and carried out and maintained by them. The execution of these programmes should proceed *pari passu* with the development of irrigation.

One further point needs to be stressed in planning for the use of water resources. As our plans proceed, we shall be faced with the needs for water-supply for the growing urban populations and for the large industrial centres that will come into existence. Projects for the use of river waters will have to take these requirements into account. Care should also be taken to see that ports, especially the larger ones, do not suffer by the withdrawal of river waters in the higher reaches.

The plans already prepared for large and medium projects do not in many cases conform to the requirements specified here. Where they do not, they should be replanned and brought up-to-date. This would be by no means difficult in practice and the additional time, labour and expenditure involved will be more justified by the results.

III : Implementation including maximisation of production

It is unnecessary to emphasise the need for ensuring high standards of efficiency and integrity in the technical and other services engaged on projects. This means recruitment by merit, careful training and close supervision by the higher officers. There should also be prompt and timely audit. Reports of special committees appointed in regard to individual projects and of public accounts committees and audit reports bring to light such irregularities as frequent upward revisions of estimates; work being done without detailed estimates; delays in measurement and over-payments and waste of funds caused in other ways. Though there has been improvement in recent years in these respects, much remains to be done to prevent such abuses. The Project Authority should devote continuous attention to this—find out where defects are and adopt suitable measures for removing them. In States which have large irrigation programmes 'vigilance units' would be useful.

Linking up with community development activities is essential for achieving the best results from irrigation projects. The use of water for irrigation, taken by itself, adds only 15 to 25 per cent to production. The main value of irrigation is that, through it, agri-

culturists are enabled to adopt the latest scientific methods—use of good seeds, fertilisers and organic and green manures and advanced techniques—and introduce new crop patterns and a diversified agricultural economy. There should be no interval between the supply of water and the universal adoption of these improved methods. The organisation of supplies and services and credit to *all* agriculturist families for such programmes through village panchayats and co-operatives is the responsibility of the community development agency.

The question of utilisation of irrigation facilities is dealt with in the Draft Outline of the Third Five-Year Plan (pages 181-82). Shortfall in utilisation may be due to (1) delay in construction of the canal system to take supplies available in reservoirs to village outlets and (ii) delay in constructing field channels and using the supply available at the village outlets. The first factor is not taken into account in the Draft Outline. There is no doubt, however, that in many cases, the canal system is lagging behind storage and that its completion should have the highest priority. There is also no doubt that, with careful planning, full utilisation should not need five years in major and two or three years in medium projects as envisaged in the Draft Plan.

IV : Financial aspects

The Planning Commission has always taken the view that no large irrigation programme can be successfully carried out unless betterment contribution is paid by areas which benefit by irrigation and water-rates are levied on a commercial basis. No special arguments are needed to justify this position; nor should there be any difficulty in agriculturists making these payments if the programmes for maximising production which have been indicated in this article are carried out speedily. Laws for betterment levy and revision of rates have been passed in most States and these should be brought into operation without delay. An exception should be made in regard to irrigation projects in chronic scarcity areas which are "protective".

We have so far dealt with large and medium irrigation projects. There are also river valleys in which irrigation takes place through chains of tanks, each one of which commands small areas. These are in many cases classed as minor irrigation works. Under our plans, large sums of money are advanced as loans to State Governments for such works. The special problems connected with these have been recently studied by a team appointed by the Committee on Plan Projects. In regard to such works, the community development organisation has a most vital part to play, as the beneficiaries have to contribute towards the costs of construction and restoration and also maintain the tank bunds and beds and channels in an efficient condition. The utility of these sources will depend entirely on the extent to which these obligations are enforced by State Governments through village institutions.

State Governments should arrange for the maintenance of separate irrigation accounts for (i) large and medium projects, and (ii) minor irrigation works, showing the capital expended, the interest and other payments due and the net returns after deducting from the income, the maintenance and other legitimate charges. These should be presented to the Assembly and discussed, so that there may be continuous efforts made to obtain adequate returns from the projects. The present state of things under which large annual subsidies have to be given from revenue accounts for these projects is detrimental to national interests.

V : Conclusions

The conclusions emerging from what has been said above may now be summarised. In the Third Five-Year Plan, the intention is to devote a high proportion of the funds available for large and medium projects (Rs. 470 crores out of Rs. 570 crores) to 'consolidation'—i.e. to obtaining the maximum results in additional production from projects already commenced. This can be achieved in two ways. Firstly, there should be improved planning and a higher standard of efficiency and integrity in the carrying out of the projects, eliminating waste of every kind. Secondly, every effort should be made to ensure that these projects are regarded as remunerative assets from which the best returns, in the shape of increased production and revenues, are secured within the shortest time. This requires close linking up with the community development movement in the areas, so that the people concerned may feel a sense of proprietorship in the projects and are assisted to adopt scientific agriculture over the entire area with improved crop patterns and a diversified agricultural economy.

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THE PAGES OF THE INDIAN JOURNAL OF POWER AND River Valley Development are regularly perused by the staff of the Water Resources Development Centre at United Nations Headquarters. We very much admire the devotion of this excellent journal to the development of power and water resources in Asia—an aim similar to our own which is, however, on a world-wide basis—with emphasis on the less-developed countries. Thus, it is a pleasure for us to have an opportunity, on the occasion of the Journal's Tenth Year Jubilee, to tell its readers something of the Water Centre's work and aims.

The Water Centre as such is a relative newcomer to the field—it was established early in 1959. However, concern at the United Nations Headquarters with water resources development problems, including hydropower development, predated the establishment of the Water Centre, for the Natural Resources Development Group had long since been concerned with the joint problems of water resources development and, as an integral part of its work on energy resources development, with hydropower development. It has dealt with many Technical Assistance projects and under its auspices studies were prepared on such subjects as Integrated River Basin Development, Industrial Use of Water, and Existing Hydrologic Services.

A considerable amount of work in the field of water resources development is also carried on by other United Nations bodies and organizations. Indeed, the advent of the Water Centre represented the culmination of several years' co-operative effort on the part of these various bodies—the Natural Resources Development Group at Headquarters, the Bureau of Flood Control for Asia and the Far East, the competent offices of several of the specialized agencies of the United Nations such as FAO, UNESCO, WHO and WMO, and other bodies. Representatives of all of these had been meeting regularly during the previous five years to review jointly their water resources development work and to try to adopt a common approach to water utilization and development problems. The establishment of the Water Centre carried this system of co-ordination one step further and more nearly provided the machinery for integrated or concerted action at the international level. The Water Centre has since become the focal point for such action.

Its specific tasks are the following:

(a) to keep the interrelated problems of water resources under continuous review;

(b) to co-ordinate the systematic study, by the various organizations concerned, of problems related to water resources development in general and river basin development in particular;

(c) to strengthen and ensure good co-ordination of technical assistance activities in respect of water resources;

(d) to foster in the case of international rivers, as appropriate, the collection of relevant data, study of tentative programme schemes and the bringing together of the parties concerned;

(e) to promote efforts towards the formulation of principles of international law applicable to water resources development; and

(f) to foster the diffusion of relevant information among Governments and interested organizations.

The establishment of the Water Centre more or less coincided with the coming into operation, also at United Nations Headquarters, of the Special Fund, which is devoted to assisting the financing, in underdeveloped countries, of resources surveys, research establishments and training institutes. Now since water projects are involved in many of the Special Fund projects, the advent of the Fund has tended to increase the scope and pace of the United Nations operational projects in the water resources field. United Nations work has also been augmented by reason of stepped-up water resources activities in the

countries requesting technical assistance. The Water Centre is callled upon to evaluate the water projects, to advise on the various stages of their planning and implementation and to brief experts.

More than one-third of recent operational water projects of the United Nations and the specialized agencies relate to basic surveys and appraisal of water resources and to the establishment and development of meteorologic, hydrologic and other water services. The remaining operational projects involve agricultural development or land use, domestic and industrial water-supply, hydroelectric power development and river basin development.[1]

An example of a concerted operational project, is the series of country-by-country water resources surveys being made in Latin America—by the Economic Commission for Latin America, the Bureau of Technical Assistance Operations and the Water Resources Development Centre, with the co-operation of the specialized agencies. These surveys endeavour to study present and potential water utilization in the context of past and prospective economic development, the survey in each country being adapted to that country's special needs and facilities.

River-basin development figures prominently in both operational and non-operational water resources programmes of the United Nations. Indeed this subject has engaged the serious attention of the Economic and Social Council for the past several years.

In 1958 the United Nations published the report on Integrated River Basin Development prepared by a panel of world-renowned experts appointed by the Secretary-General. This report presented the challenge inherent in orderly development of the rivers of the world and discussed the lines along which the experts believed the United Nations and its specialized agencies should move in dealing with it.

Pursuant to the panel's recommendations work is underway on a number of different aspects of this complex subject—by the Water Centre, by the Regional Economic Commissions, the Special Fund, the Bureau of Technical Assistance Operations and by several of the specialized agencies. Asian readers of the Journal of Power and River Valley Development need not be told of the work on the Lower Mekong Basin which is a prime example of concerted action in this domain under the United Nations auspices.

The Water Centre's responsibility for co-ordination is especially pertinent and important where river-basin development is concerned, since the success or failure of river-basin schemes depend on a variety of problems which are usually the concern of several organizations.

In addition, the Water Centre has begun a series of systematic economic and other studies on river-basin development as a follow-up to the abovementioned panel report. For example, a study is underway on cost-benefit analysis and investment requirements analysis as well as on the economic impacts of multi-purpose projects. Another study will concern comparative administrative machinery.

Still other studies by the Water Centre, undertaken mostly in collaboration or co-operation with one or more of the specialized agencies, concern such subjects as water resources survey techniques, groundwater development, river-flow evaluation, water-pollution problems and so on.

A study on Large-Scale Groundwater Development will be published by the Water Centre in time for presentation to the Fourth Regional Technical Conference on Water Resources Development to be convened by ECAFE in December 1960 in Ceylon. Preparations for this study began with a systematic review by the Water Centre of the experience and work on groundwater in technical assistance programmes and otherwise. Then an outline for the study was prepared with the help of consultants and the competent staff of FAO, UNESCO, WMO and WHO, after which a draft report was discussed at a meeting of consultants specially convened for this purpose. The finalised version is now being readied for publication. The study addresses itself primarily to those administrators who are responsible for comprehensive development of groundwater in extensive areas. It deals not so much with purely technical problems as with questions of administration, organization and economics.

The studies on economic aspects of river-basin development and of groundwater development are in line with the emphasis the Centre places on the economic aspects of water resources development problems. At least two other economic studies are in progress—one on the cost and value of water for different uses and one on the economics of demineralisation of saline water. The first-mentioned will be a follow-up study to that on Water for Industrial Use. It will provide a guide to the factors which should enter cost estimates and possibly will provide a yardstick for the appraisal of proposed projects—with a view to meeting the needs of administrators and others responsible for formulation of water policy, including allocation of water in water-short areas.

The study on demineralization is, if anything, even more important—for no single achievement would do more for the improvement of living conditions in arid zones than the discovery of economic methods

(Continued on page 18)

[1] An annotated list of these and the other projects in water resources development may be found in the First Biennial Report of the Water Resources Development Centre (United Nations document E/3319), issued in April 1960. This report also provides a full account of the work of the Water Centre and of the related work of the specialized agencies.

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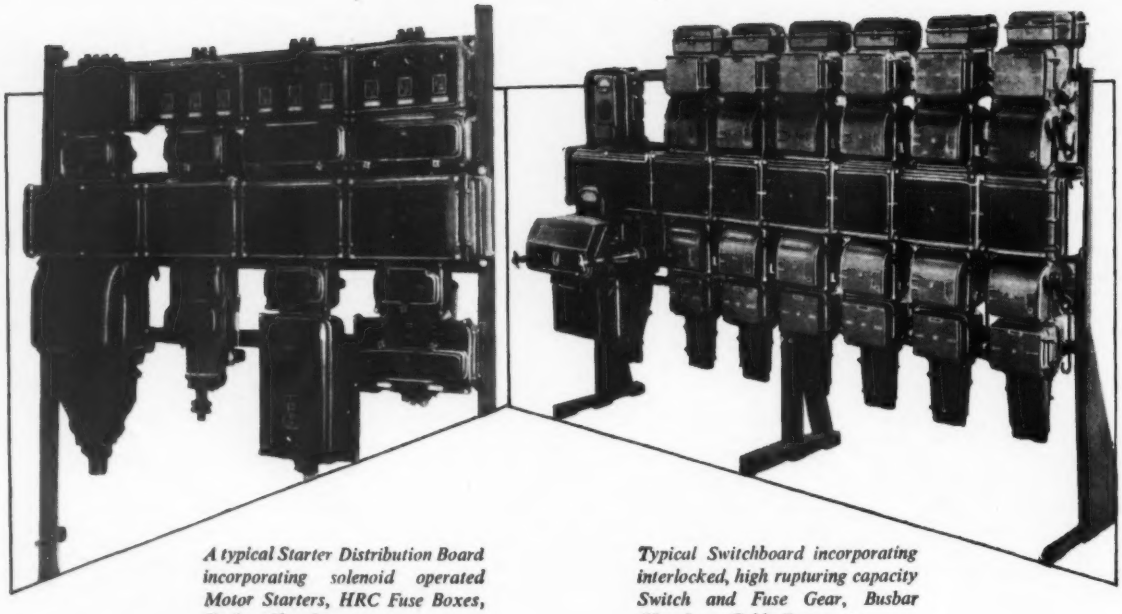

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World Wide Valley Development: A Perspective

A LARGE PART OF THE SURFACE OF OUR PLANET IS nurtured by free-flowing fresh-water courses.

An authoritative report of the United Nations: "Integrated River Basin Development" (1958) lists 19 river basins, each more than 1 million square kilometers. Among these great basins are the Congo, the Nile, the Ganges-Brahmaputra, the St. Lawrence, the Mississippi, the Yangtze-kiang, the Ob, the Zambesi —to name but a few. In this category are the giant river valleys which dominate whole continents or sub-continents.

Lesser river valleys, some 78 in number—those in the scale of 100,000 to 1 million square kilometers—include the Columbia, the Indus, the Volta, the Mekong, the Rhine, the Loire, the Ural, the Tigris-Euphrates, the Awash and the Don.

Some of these great basins support large and numerous populations. Many still beckon as the frontiers of great promise. Each basin—and the tributary basins—is marked by its own particular history and a special set of contributing and controlling factors —some natural, some man-made. Each basin may be significantly different from all others—but all have much in common.

The shores of our great salt oceans and the banks of our fresh-water rivers have been magnets to settlement and the requisite of flourishing civilizations since man's history began.

As our world family of man grows in number, our rivers above and below the ground in centers of greatest population are fast becoming overburdened with the life-maintaining duties water is required to perform. Rivers uncontrolled and without man-made storage reservoirs frequently fail to satisfy the needs of the people in time of drought. And, indeed, rivers uncontrolled in seasonal flood may bring pestilence, destruction and death.

How to make our rivers more serviceable in sustaining, protecting and nourishing more people where they are *now*—to feed life and to save life—the most elementary of human wants, is a task barely begun. How to open up the cornucopia of progressively greater benefits, beyond bare human needs, which the intelligent rebuilding of our river basins will provide is a challenge still dimly understood. The sparsely habited river basins potentially amenable to the spillover of burgeoning population of the next half century are the primary frontiers which question those who say our globe cannot be hospitable to countless millions of children yet unborn.

For we as a world of people are not without the means—technical and economic—to wrest the ingredients of a higher standard of life and living from the treasures and values of our rivers, great and small.

Among the tools in our hands, if understood in our minds, is the demonstrated technical and economic feasibility of integrated and comprehensive river basin development. Using the river course as a central source of latent benefits, viewing the river and the land, and the people they may serve, as a whole and workable unity, mobilizing the knowledge and technical skills of many specialisms, and distilling from them the scheme for dams, reservoirs, canals, turbines and generators properly placed and imaginatively integrated for operation as a system is the key to rebuilding our river basins. By this approach, guided in each instance by an intelligent estimate of existing and potential human needs for water, food, fibre and electric energy, the mobilization of human energies and the will to act and the scheduling of time and capital for benefits to be obtained can be brought within reach of human decision and choice.

In this approach to the rebuilding of our river valleys, new opportunities will arise for creative adaptation of the institutions of central and local governments to serve its citizens more effectively. New and diverse means to stimulate private economic action with risk and profit will be discovered. Greater national goals will be attainable as the basic economy is broadened by bringing idle or wasting natural resources into use. Moot conflicts of nation-to-nation interests centered on international rivers can

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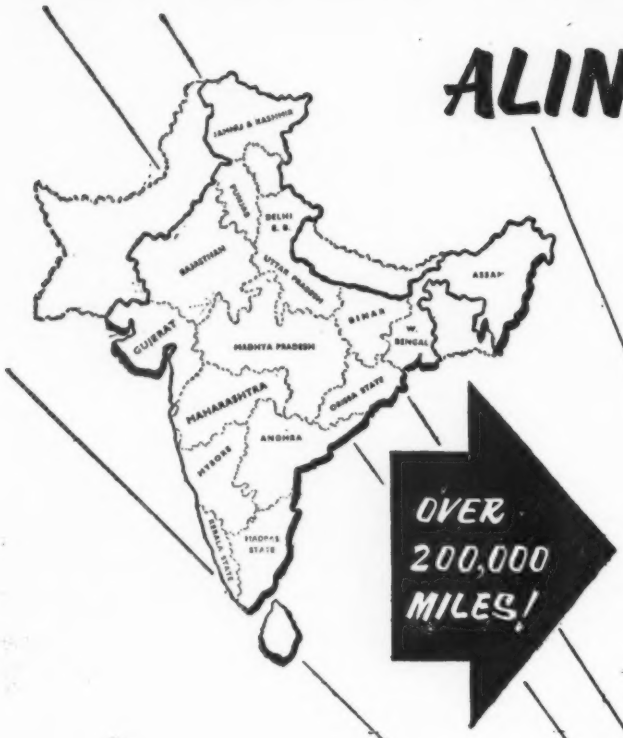

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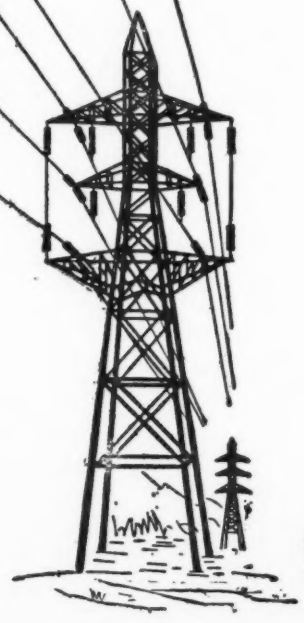

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Economics of Energy Production in India

IN A DEVELOPMENT ECONOMY LIKE OURS THE PROBLEM of supply as well as consumption of energy assumes many significant facets. In fact, the energy picture of India carries with it all the features of an underdeveloped economy struggling hard to develop itself. Accepting this as the main background, we may tackle the issues relating to energy from at least four angles. They are allied to (a) the quantitative aspects of production and consumption of energy; (b) changing pattern in the use of energy; (c) efficiency with which energy is produced or consumed; and (d) regional balance in the development of energy resources.

Quantitative Aspects

The quantum of production and consumption of energy is bound to alter with the quickening tempo of economic development. With the implementation of the large industrial and transport development schemes, the demand for energy, especially of primary energy, will be intensified. One of the best methods of forecasting demand for energy is to relate energy requirements, as closely as possible, to individual sectors of the economy.

NCAER's study on "Demand for Energy 1960-1975" accepts more or less the lines of development postulated (with minor changes) in the Second Plan, as the basis for sectoral projections of energy demand. While the per capita income is expected to be doubled in 20 years in 1975-1976 (from Rs. 281 to Rs. 564), the National income is hoped to be more than twice the 1955-1956 level.

On the basis of the assumptions involved in the respective growths, forecasts have been made regarding the type of energy and its total consumption by the major sectors. These are as under:

In MTCE

	1955	*1960*	*1965*	*1970*	*1975*
Industrial energy	17.91	28.69	45.40	67.6	105.0
Transport	12.09	14.88	18.7	21.7	28.4
Domestic Primary	4.3	12.0	18.9	32.7	58.5
Domestic Secondary	93.7	92.5	95.1	96.3	79.0
Services & Rest	3.1	6.0	12.0	22.0	45.0
Total Effective	131.1	154.1	190.1	240.3	315.9

Allowing for losses, etc., the ratio of net primary to secondary energy will rise sharply from 0.5 to 3.6, and primary energy will have exceeded secondary energy sometime between 1960 and 1965. In per capita terms, energy consumption is expected to shoot up from the present 0.2 tce to 0.62 tce in 1975.

Of total energy itself, the average rate of increase will be about 5 per cent per annum, primary energy rising by 10 per cent. During the two decades lasting from 1955 to 1975, the share of coal is expected to fall from 79.5 per cent to 71.2 per cent while that of hydro-electricity and petroleum will increase from 6.8 per cent to 12.6 per cent and, from 11 per cent to 13.9 per cent respectively. The following table presents a detailed picture of the situation.

(In percentages)

Year	*Coal*	*Hydro*	*Petroleum*	*Nuclear*
1955	79.5	6.8	13.7	—
1960	76.5	10.6	12.9	—
1965	74.5	11.9	13.0	0.6
1970	72.5	12.6	13.2	1.7
1975	71.2	12.6	13.9	2.3

Obviously, the fall in the share of coal is expected to be made up by the increasing use of hydro-power, whereas petroleum's share will remain, more or less, constant. So far as nuclear power is concerned, at the present moment at least, it compares unfavourably with coal power both in terms of capital and unit cost; no doubt, it may compete with coal power by 1970 or 1975, when nuclear costs are expected to come down. However, in the next decade, its contribution will not be of a large magnitude. Therefore, it is clear that even in 1975, India will have a coal-based economy. In fact, even by 2000A.D., as much as 55-60% of total primary energy is expected to be met by coal.

It is important to remember that the above estimates may err either on the side of overestimation or underestimation. They are governed by the sequence of events related to production, investment and income in agriculture, industry, transport and misc. services allied to economic growth in the next 15 years. Hence, a big margin has to be allowed for uneven rises and intervening levels in the overall

development of the country. Notwithstanding these uncertainties, the demand forecasts for energy can be broadly accepted.

Changes in the Pattern of Energy Consumption

Here, it is possible to draw two sides of the picture. First of all, we may consider the relative positions of primary and secondary fuels in our country and, secondly, the predominant types of primary energy used in various sectors of the economy.

Between primary and secondary fuels, the latter occupies a notable position. Energy requirements tend to grow at a slower rate than the Gross National Product and out of 70 per cent of energy used for consumption in domestic and other services, a major portion is met by secondary fuels. For instance, in 1956, out of the 143 million tons of coal equivalent (MTCE) of gross energy consumed, nearly 95 MTCE was from secondary fuels. The ratio of the two coefficients is one of the main indicators of the level of economic growth. The higher the quantum of energy used as a productive factor, the greater is the rate of growth. According to rough estimates made by the NCAER, the income-elasticity of energy consumption is 0.6 for all types of energy, 0.18 for secondary fuels and 1.58 for primary energy. The low elasticity of secondary fuels which is mostly used in rural areas is significant. And, this proves conclusively that corresponding to the development efforts, the response from the rural sector is far from satisfactory.

Now, we may analyse the utilisation pattern of energy consumption (between 1950-1955) by sources and in sectors of growth. In the field of primary energy the share of coal registered a decline from 83% to 79.5%, as compared with the increase in the consumption of hydro power from 6.3% to 7.2% and from 10.7% to 13.3% in the case of oil. Despite a slight fall in the case of coal consumption, it continued to be the dominant feature in the primary energy-pattern.

The table given below shows the sector-wise consumption of energy in India between 1950-55.

In MTCE

	1950	*1955*
Industry	15.24	17.91
Transport	10.21	12.09
Domestic Primary	1.6	4.3
Domestic Secondary	90.0	93.7
Agriculture		
Service etc.	1.8	3.1
Total Effective Consumption	188.85	131.10
Total Primary	30.2	37.4
Total Secondary	88.65	93.70

As already stated, the predominance of secondary fuels and the slow growth in the uses of primary energy, even in the domestic sector, is evident.

One of the most significant trends noticeable in the energy-economics of today is the increasing inclination towards dieselization in transport services. Among the various states, Madras takes the lead with 88% of diesel vehicles. In fact, the world-wide tendency towards dieselization is mainly due to the economy accruing from the substituting of diesel for petrol as fuel. The diesel engine is superior to the petrol engine in the conversion of heat energy into mechanical energy. Besides, diesel oil permits a higher mileage per gallon—40% higher than in the case of petrol. In fact, this is one of the most potent forces behind dieselisation, in view of the importance of fuel as an item of cost. The technical economy resulting from the lower price of diesel oil is not intrinsic in the latter's use, but largely dependent on public policies concerning relative price of oil and petrol.

Efficiency in the use of Energy Resources

The effectiveness of the contribution of energy to economic growth is best measured in terms of its relative use as a producer good and as a consumer good. Merely to augment its total supply does not solve the problem. The real test lies in influencing its efficient use. Improvement in the ratio of product output to energy input may result from various reasons such as, switching from one fuel to another, by extensive capital re-equipment, or simply by being more intelligent in the use of energy supplies. But, the question which substantially affects the total demand for energy is the extent and speed with which these developments continue.

In India, however, the technique of fuel utilisation leaves much to be desired. That there is a wide disparity between *total* consumption of energy and the amount of energy *usefully* consumed must be recognised. The overall efficiency remains at 30%, i.e., if all the fuels were capable of being utilised without any heat loss, the total amount of fuel required would be less than one-third the present supplies. As a rule, fuels can be more efficiently utilised in the generation of heat than in the production of power. In industry and households, where use of heat predominates over the use of mechanical power, efficiency is of the order of 50% and 40%, respectively. Two other sectors—agriculture and services—are also above average in their efficiency. But in railways the efficiency is as low as 4%. Most people are not aware that for every ton of coal burnt in railway locomotives, the energy equivalent of only about 90 lbs. of coal is actually harnessed for traction, the rest being more or less wasted.

Apart from this, the wastage occurring from burning of secondary fuels like dung, firewood, etc., is considerable. According to estimates made by the NCAER in "Domestic Fuels in India", nearly 300 million tons (37 MTCE) of wet dung are burnt every year for fuel which, in terms of fertiliser potential,

is tantamount to the burning of the annual production of 12 Sindri factories. Again, in the case of firewood out of 32 MTCE nearly 27 MTCE comes from non-forest area which is less than four times the forest expanse.

Naturally, this causes great injury to the maintenance of the soil. By substituting primary fuels for these secondary ones, and diverting the latter to agriculture and allied activities, it is possible to achieve not only a better overall efficiency in energy use, but also, a substantial increase in agricultural production.

So far as the demand for domestic heat, especially, in urban areas is concerned, the large reserves of non-coking coal offers great scope for exploitation. For this purpose, a coal carbonisation programme could be drawn for supply of gas and soft coke. No doubt, there is the contribution of kerosene and electricity, but it can be only of marginal significance considering the largeness of demand for domestic heat in urban area which is expected to rise by 50% during 1960-1970. On the other hand, the rural demand is expected to remain almost inelastic, rising only by five cent. And, this can be easily met by raising fuel plantations in the villages and transporting fuel wood from other forest areas within a radius of 30 miles. This in turn, would make it possible to divert valuable dung and other wastes now used for domestic uses, to manuring purposes. By this measure, it is possible to raise an additional output worth of Rs. 2,000 crores in 15 years.

Regional Balance in the Development of Energy Resources

This is of vital importance in a developing economy like India. Regional planning is necessary both from the point of view of balanced development of the country and the maximum exploitation of local resources which it permits. Since the general objective is one of effecting rapid industrialisation all over the country in future years, it is but right that due attention should be given to the development of energy resources as well. The close link between industrial growth and production of energy is too obvious to need any further elaboration.

The scope for attaining regional balance in the development of energy resources is three-fold. Firstly, there is the entire field of primary energy constituted by such items as coal, hydro-power, and mineral oils. Secondly, there are what are called secondary fuels like animal and vegetable waste, which, of course, fall outside the limits of modern technology.

Given these resources, other questions relating to the demand and supply aspects of energy resources crop up. Further, we are faced with the problem of irregular distribution of energy resources with the result that some states are either self-sufficient or surplus in power, while other states are deficit. For example, Delhi, Punjab, Uttar Pradesh, Gujarat, Madhya Pradesh, Mysore and Madras are deficit in power, whereas Kerala, Maharashtra, and Rajasthan are either self-sufficient or surplus in their resources. No doubt, where the distance between the consuming and producing centres is not very long the problem could be esaily solved by hauling power from the surplus state to the deficit region. For instance, from Gujarat to Maharashtra, from Rajasthan to Madhya Pradesh, from Kerala to Mysore and so on. But our country is one of long distances and with the high cost of transport facilities, the entire issue assumes serious magnitudes while planning for energy development. To some extent, it is possible to solve the problem on a zonal basis but ultimately, some definite way has to be found. It is particularly in this context, that a case for the development of atomic energy resources can be built up.

If the total generating capacity reaches 50,000 M.W. in the middle of 1980's not more than 60% of it could be met from hydro-power and it would be uneconomic to rely fully on coal for the remaining 40%. After all, if coal has to meet 40%, coal consumption should be 70 million tons per year and the cost will be prohibitive. Besides, a large proportion of India's coal reserves are of low grade variety. One must also take cognizance of the possible saving in fuel costs, as the price of coal used in conventional steam stations tends to go up. Moreover, there is the possible saving in the mining cost of coal required for a superthermal station and its movement by rail. It is true that the setting up of atomic power stations will mean a big fortune in terms of cost, but such stations should be established as close as possible to the reserve centres. This will definitely reduce the cost of the scheme. Moreover, the cost phenomenon is only a short term problem; because, in the long run, the cost difference per k.w.h. energy between nuclear energy and other conventional sources will be made good as large-scale generation of electricity is undertaken from nuclear energy.

A basic advantage, which India carries for the development of atomic power, is the extensive reserves of natural uranium and thorium. The reserves are estimated to be of the order of 15,000 tons and 150,000 tons, respectively. Together, they are equivalent to 600,000 million tons of coal. Plutonium, which is the main substance used in producing atomic energy is a result of the combination of thorium and uranium. The vast reserves of these two items ensure an easy access to the principal product used in atomic power.

However, the development of nuclear power should be sufficiently forestalled by the proper utilisation of primary energy and other secondary resources. Unless this is done, there is no point in taking too big a leap in favour of atomic power. India is still underdeveloped, or, at best a developing economy where primary energy constitutes only about a third of her total

energy consumption. Yet, by far it is the most significant constituent of both industrial and transport sectors. Even in the industrialised countries of the West, it caters to more than 95% of their total energy intake and is rightly considered as the backbone of the modern industrial world. Apart from the problem of expanding the consumer market for primary energy, another challenge, that of maximising efficiency and minimising costs, will remain a very real one. In this context, it is pertinent to quote the views expressed by the Rt. Hon. Richard Wood, Minister for Power, U.K.*

"It is sometimes that, in the 'average' industry, the proportion of energy costs to total costs is relatively low—under 5 per cent. But industrial costs are built up from 5 per cent items. If we, as an industrial nation, fail to minimise all these items, we shall certainly be unable to keep our place and improve our standards of living in an increasingly competitive world." ,

(*) "Energy in Variety to Match Industrial Growth", The Financial Times, pp. 35., Annual Review, 1960.

(Continued from page 21)

ECONOMIC ADVANCEMENT OF UNDER-DEVELOPED COUNTRIES

under the United Nations Expanded Programme of Technical Assistance, which is 10 years old this year. Its budget is now just over 33m. dollars per annum and the programme is fully international in character; 86 countries have contributed to it and 140 territories have benefited from it. Many countries are now both givers and receivers as is shown by the fact that, in 1958, experts were drawn from 64 different countries and trainees were sent for training to 68 different countries. These experts employed in the scheme are advisers or trainers and teachers rather than executives.

To sum up: The economic challenge of the future must be met in the main by the energy and resource of the people who wish to enjoy a higher standard of living. Limited help can and should be given to under-developed countries by those who are more advanced economically. This can take the form of financial aid and assistance in the training of technical personnel.

But help from outside can be effective only in providing the initial kick-off. Enduring success depends upon the will and ability of the indigenous population and the presence of adequate natural resources. It also depends upon the rate of growth of population being less than the rate of growth of national income.

(Continued from page 13)

WORLD WIDE VALLEY DEVELOPMENT

be eased by the prospect of mutual benefit. The opportunities for beneficial change are limited only by men's minds and animosities where harm to one another is deemed of greater value than benefit for both. The future promise of the impersonal and seemingly eternal river can be the standard around which co-operative energies can rally and go to work for self and others.

When river basins are studied and planned to find a transcending unity of physical treatment, the preservation and encouragement of regional or national strength through diversification of human activity and benefit can be a primary by-product of great tangible and intangible value. And it is these values that are so frequently sacrificed, unwittingly, when a river course is butchered and underdeveloped as single projects unrelated in the mind or in subsequent operation are fastened upon irreplaceable sites along the stream.

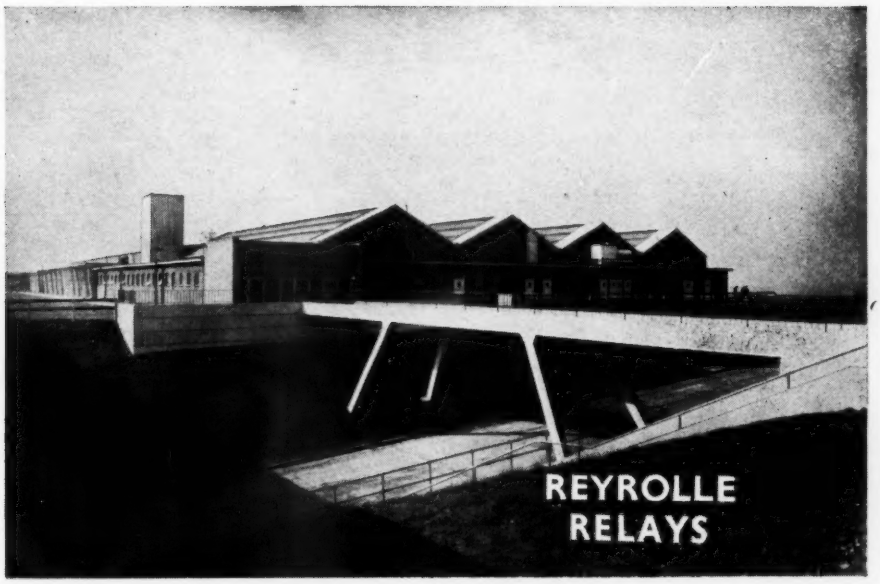
The record of human achievement is closely and inextricably tied to the ebb and flow of the rivers and streams that run their courses from source to sea. Water—suitable for plant, animal and man—will continue to be a controlling element in the peaceful and fruitful habitation of this planet. New technology and tested applications of better managerial methods now make our rivers more amenable to basic and productive reorganization. But a basic requirement still needs to be met: we must lift our sights to envisage what can be done and how it will make our rivers more useful in more ways to more and more people.

(Continued from page 12)

CONCERTED INTERNATIONAL ACTION ON WATER.....

of purifying saline water both from the sea and from underground sources. UNESCO has been rendering invaluable services through the encouragement of research and scientific studies in this field. It is felt that the time is now ripe for the study of the economic aspects, including in particular, the delineation of areas and situations of potential economic application.

In conclusion, it may be stated that the Water Resources Development Centre is always animated by one over-riding consideration and objective: that of assisting in the most efficacious way it can, the economic development of the less-developed countries of the world, within the broad framework of United Nations activities in the economic field.



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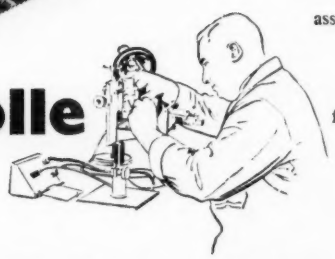

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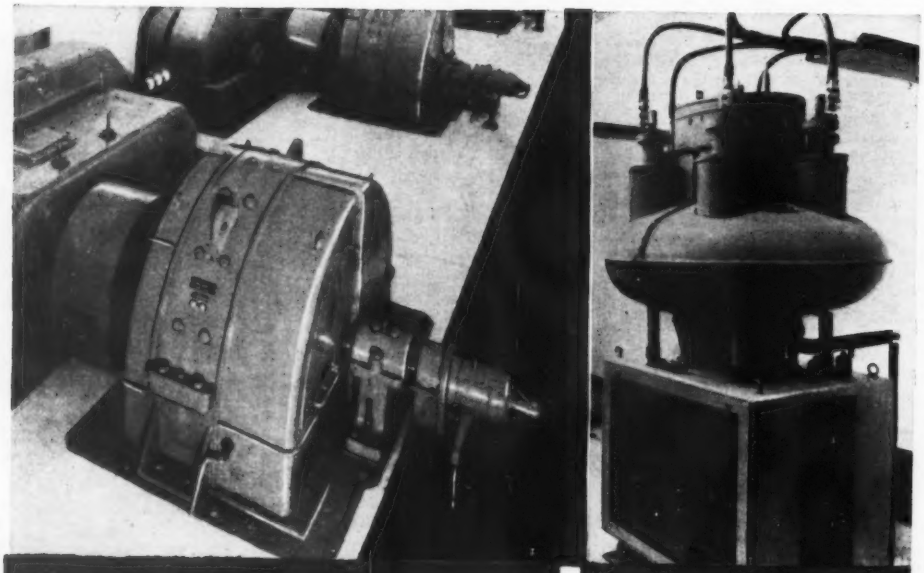

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Economic Advancement of Under-Developed Countries

THE POLITICAL OBJECTIVE OF MOST COUNTRIES IS TO establish and maintain domestic and world conditions in which their people can live in peace and security.

Within this framework the economic objective is to improve the standard of living of their people. A nation may also have other objectives—cultural, artistic, religious, philanthropic and so on.

In this article it is intended to discuss only the economic objectives and the reason for mentioning the others is simply to remind us that this is only one —albeit an important one—of the desirable ends which good government and human effort should seek to achieve.

One measures the standard of living of a people in terms of the satisfaction of the basic human needs—food, clothing and shelter—and in the degree of comfort, luxury, leisure and cultural pursuits that can be attained by all the people through their own efforts.

The basic requirements depend to some extent upon climate. The ability to satisfy them depends upon the energy and ingenuity of the people, the presence of water supplies, the fertility of the soil and the resources that are available and are usefully exploited both on and below the land surface.

Man is the only animal that uses tools and it is because of this attribute plus his ability to think and to communicate thought processes, first by sounds and later by writing (using tools) that he has established a dominant place in the animal world. It is by being able to think out new ways of doing things and by making and using suitable tools to do them that he has been able to improve his economic lot.

History shows that he has been busy in these ways since the record began. For a long time he made and used hand tools; later he made bigger tools and employed animals to work them; and, later still, he used the force of falling water and of the wind on really big tools to do more work than he could possibly have done with his unaided strength.

This idea of employing the forces of nature as a substitute for and multiplier of human muscle was—after the invention of tools themselves—the next greatest step forward that economic man has made.

In retrospect it is easy to see the further chain of events. Someone discovered that by boiling water it is converted into steam, and that steam under pressure can cause an engine to do work. Coal was pressed into service to boil the water. Oil was discovered and a way was found for exploding it directly in an enclosed space to create pressure and cause another kind of engine to do work.

These so-called power-driven engines are the tools which have enabled man to provide for his needs in agriculture, in the fabrication of other tools and structures, in transport, in communications on a scale that would have been quite impossible of achievement without them. The Industrial Revolution is their offspring.

As man became aware of his ability to do so many new things, the scale of his demands soared nearly pro rata, and those who acquired the "know-how" used it to an extent that over a long period their standard of living has become much higher than that of the others who have not had the fortune, the urge, or the organisation to grasp the idea and turn it to good account.

There is a quite natural tendency to envy those who have pressed nature into their service in this way. But for them it has been a long uphill struggle.

For example, while a man occupied himself in making hand tools, he was not producing food, clothing or shelter. He had to sacrifice an immediate good for the prospect of being able to provide and enjoy more later on.

This idea of immediate sacrifice for ultimate betterment is inherent in the creation of all so-called "capital" assets. The "tightening of one's belt"—so that present consumption is less—the use of the time and energy so set free, from the production of things for immediate consumption, to make structures and tools of a durable character which will enable the

achievement of increased output of desirable goods throughout many years in the future, these are the essential requirements.

But it has never been easy to get this process started. Even when using hand tools man has had to be busily engaged in providing for his daily needs. Self-discipline has been needed to devote time and effort to building, say, power-driven machines which could confer no benefit until they had been successfully constructed, perhaps months or years ahead.

The problem in every industrial country has been, to think up, to invent tools, devices, machines, that can be beneficially used, and to endure the temporary loss of the fruits of labour whilst these devices are being constructed and made ready for service.

The countries that pioneered in this field had a double disadvantage. They had to acquire the "know-how" as they went along, and they had to exercise the discipline of saving to finance the construction of the increasing range of capital works.

Today the "know-how" of most industrial activity has been disseminated throughout the world. It is true that each individual has to acquire skill and technical knowledge afresh. It is not a hereditary gift, but it is available for the taking in books, laboratories and workshops. There is a storehouse to be drawn upon by those who wish to do so.

Nor is the discipline necessary for the initial kick-off as rigorous as it once was. Some financial facilities are being made available by the more industrially advanced countries to assist in the provision of the first round of equipment that is so necessary to get the process of self-betterment started. Quantitatively it may be thought to be inadequate—and indeed everything possible should be done to increase it. But it must always be remembered that such help can at best set the process in motion, and that its momentum can be maintained only by the intelligence, organisation and application of the people who wish to benefit from it. There is no long-term solution of a country's problems of economic betterment and improved standard of living other than through the efforts and self-discipline of the people concerned.

How then does one make progress towards economic improvement? Food, clothing and shelter are still the basic needs and it is essential for all, or at any rate most, of the people to have these needs reasonably satisfied as a pre-requisite of other advancement. The hour-to-hour requirement is food. Unfortunately, nature, the great provider, is a fickle jade. The greatest single uncertainty in satisfying man's physical needs is the variability of the harvests. The best laid plans can be frustrated by storm and drought, and a run of bad fortune in this respect for several successive years can be disastrous. One of the first things, therefore, is to mitigate, as far as we are able, the effects of adverse weather. Irrigation and more irrigation is a first step; fertilisers and more fertilisers are a second; and some means of storage of surpluses from the fat years might well be a third. Much can also be done by providing good seed, by planning a balanced production of essential foods and the best form of crop rotation.

The volume of food required will depend upon the population. If the number of people to be fed is increasing more rapidly than the increase in agricultural production, the prospect of economic betterment is likely to be impaired unless these people can be employed on work that will enable the country to buy food from abroad. This presupposes a corresponding export.

But, apart from pressure of population, profitable exports are essential so long as a country is not self-sufficient in indigenous resources—and what country, if it could afford it, would not wish to import raw materials or manufactured goods (either consumer or capital) as the quickest and surest way of accelerating its economic progress?

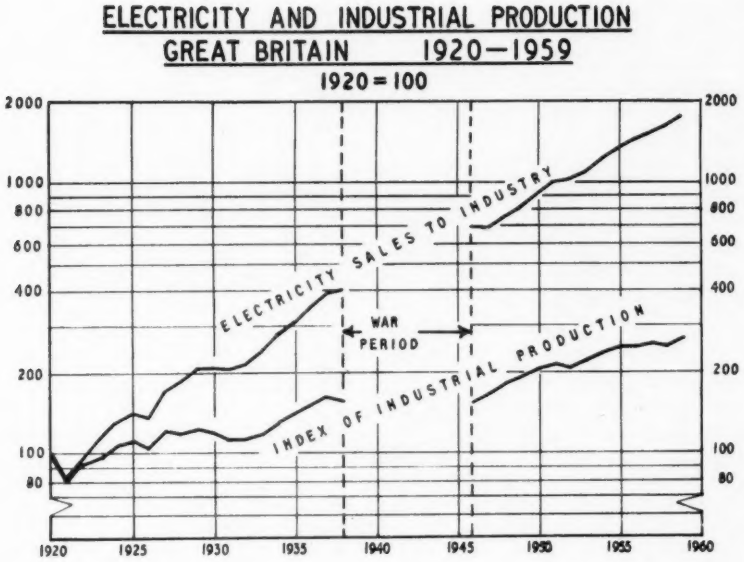
Thus to ensure progress one must develop the basic internal production of the country in the most efficient way and at the same time produce enough things that are saleable abroad to pay for the raw materials that are lacking or the manufactured goods that cannot yet be made, or so well made, at home, but which are essential to further betterment.

One way of doing this is to multiply human effort and human achievement by harnessing the sources of power in nature. In general, this is the main way. There are a few countries rich in natural resources who can simply sell these resources as they stand, or rather sell the rights for their exploitation by others, and live on the proceeds of the sale. That, however, is the privilege of the few, and for the rest of us it is essential to our economic wellbeing that we develop and utilise the indigenous sources of power and, where these are insufficient, buy these sources from others who have them in excess.

Within this framework of desirable activity there will be priorities.

It will be recalled that most of the effort that does not immediately produce consumer goods is in the nature of a temporary sacrifice, an act of discipline, to secure a future benefit. All capital expenditure is of this nature. But in a country starting from scratch there is a limit to the amount of restraint that people can be expected to exercise so that they may enjoy something later on. If people are already at a mere subsistence level there isn't anything that they can defer.

Generalising, it will be apparent that in the early stages of economic progress it is the things that can be produced with the smallest deferment of benefit, both in amount and time, that will have the greatest appeal to ordinary people. Stated in the language of


ELECTRICITY AND INDUSTRIAL PRODUCTION
GREAT BRITAIN 1920—1959
1920 = 100
2000
1000
800
600
400
200
100
80
ELECTRICITY SALES TO INDUSTRY
WAR PERIOD
INDEX OF INDUSTRIAL PRODUCTION
1920
1925
1930
1935
1940
1945
1950
1955
1960

an economist, these are the things which require the smallest capital investment and give the quickest return. The political truth of this will be apparent to legislators. It would seem to imply that not all the effort should be directed towards the large, complicated, expensive schemes, but that a portion—perhaps in the early years a substantial proportion—should be devoted to better agricultural implements, seed and fertilisers, equipment for cottage industries and, in general, the hand or animal-driven tools that help people, working on a small scale, to produce more.

Amongst the large projects there will probably be some room, in the early stages, for choice of those which achieve a given object or provide a given service with a minimum of capital expenditure.

The effect of successful, economic activity is cumulative. The process is self-generating and the benefits are real, provided the population is not increasing at as fast a rate as the economic gain. It is the improvement in income *per capita* which is the broad criterion of improved living standards. Experience and judgment is necessary to determine the proportion of this income that should be left at the disposal of the individual for his immediate benefit. However, this is a political matter and therefore beyond my scope.

Now a word to illustrate the truth of what has been said about the economic benefit from the development of sources of power.

It has been shown that the income per capita is closely related to the consumption of natural energy and since electricity is the most general form of energy now in use the standard of living can be related to electricity consumption.

The following table shows the income and the electricity consumption per capita for various countries.

ELECTRICITY CONSUMPTION PER CAPITA (1958)

Country	*National Income per capita (U.S. dollars)*	*Electricity Consumption (Gross) per capita (kwh.)*
U.S.A.	2,095	4,164
Australia	1,117	2,077
U.K.	984	2,186
Denmark	906	904
Belgium and Luxembourg	899	1,572
France	819	1,395
West Germany	775	1,841
Netherlands	715	1,255
Italy	431	936
Spain	295	551
Japan	255	906
Mexico	252	296
Argentine	189	370
Yugoslavia	159	395
Turkey	143	88
Brazil	118	295
India (1957)	60	36
China (1956)	55	41
Indonesia	21	18

(Table cont'd on next column)

The table shows that even if we look no further than half-way down the list, some countries have a per capita consumption of electricity which is less than a quarter that of the highest shown. Thus, even if electricity consumption in these countries doubled every five years, i.e. increased at twice the rate experienced by those at the top of the scale, parity in per capita consumption of electricity would not be achieved for twenty years, assuming a 1:4 ratio at the present time.

The important correlation between the use of electricity in industry and the index of industrial production is illustrated by the attached diagram showing the relationship that has been experienced bteween the two factors in Great Britain since the year 1920.

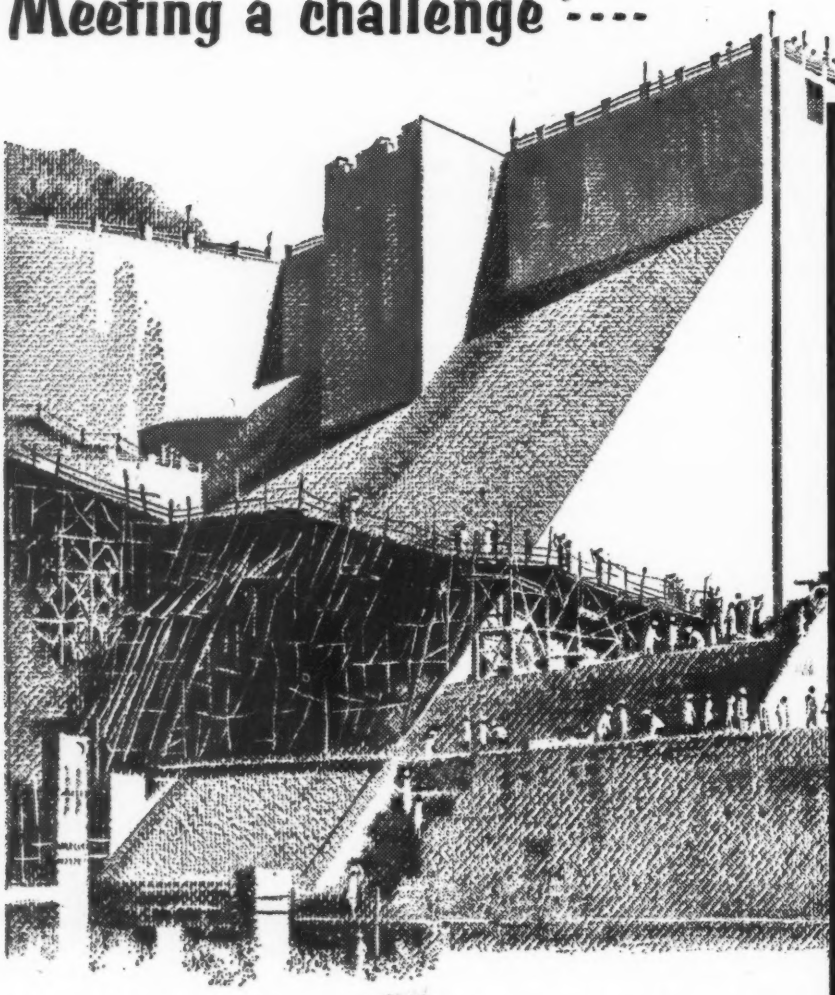
To render possible this rate of progress in under-developed countries some outside financial aid would seem to be necessary. Such an arrangement is by no means easy to make. If the aid is provided as a loan on commercial terms the annual charge is substantial, and if this charge has to be paid in foreign currency it may well require a disproportionate part of the proceeds of the exports of the borrowing country to requite it. If it is to be rendered on uncommercial terms, it has to compete with that given to other under-developed countries, and the source of such aid is limited to that which the donor countries can afford to give after meeting their own internal obligations.

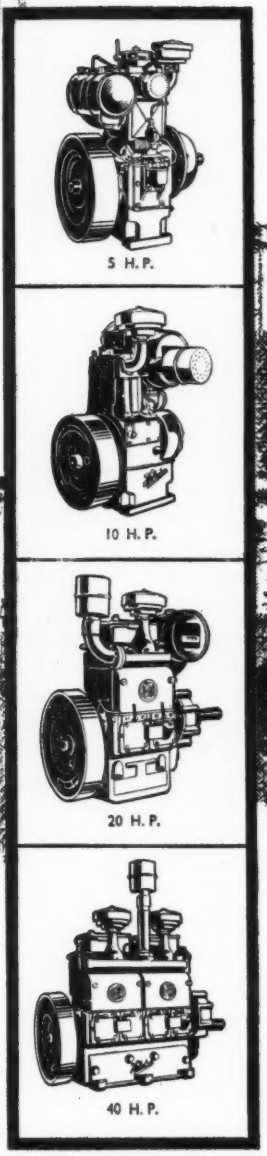
But important as is the need of under-developed countries for financial assistance from those well-placed to render it, the need for these countries to train a sufficient number of their own nationals as engineers and scientists is equally pressing. Only in this way can the benefits and the greater "know-how" of the advanced countries be shared by all. The establishment and expansion of technical education institutions in the under-developed countries must necessarily be dependent on the existence of suitably trained personnel to staff them. Although an impressive number of young men from these countries receive theoretical and practical training in foreign universities and manufacturing establishments either under private arrangements or under scholarships and fellowships granted by governments, private undertakings, trusts and international organisations, it is fairly safe to say that the numbers involved are not nearly sufficient to meet the growing need.

The possession of an adequate educational system in one's own country is an essential attribute of nationhood and is very desirable in terms of social advancement. The expansion of higher educational facilities in local institutions is being encouraged in the under-developed countries by the help provided

(Continued on page 18)

Meeting a challenge ----





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Some Contemporary Problems of Water Power Development

THE PRODUCTION OF GREAT AMOUNTS OF ELECTRIC power (reaching hundreds of billions of kilowatt-hours per year in some countries) and a steady reduction of the production cost of electricity sent out to the consumer are the paramount tasks in power engineering and electrification.

The increasing specialization of the individual types of modern power stations operating in a complex power grid and the ever increasing irregularity in power consumption give prominence to the hydropower plants. They are well adapted to carrying rapidly varying electric loads and they generate power at a much lower cost than power stations of other types.

* * *

The countries of the world may be divided at least into two characteristic types as regards their power sources: smaller countries with more or less uniform natural conditions throughout the entire territory, rich in water resources, but having practically no fuel resources of their own, and countries covering vast territories with variegated natural conditions, possessing ample raw material and power resources of different kinds.

The hydropower stations in a number of countries of the first group produce cheap electric power at relatively uniform duty, supplying large power-consuming enterprises. In some cases the chief object of export of these countries is electricity which is transmitted abroad directly over power-transmission lines and indirectly in the shape of goods manufactured by power-consuming industrial enterprises.

The main tendency in the countries of the second group is the mass generation of base power at the lowest possible cost by thermal power stations so that the peak, mainly hydroelectric, power should balance out the gap between the current demand and supply in the power systems. The share of hydropower in the power balance of a number of countries in this group will increase for some time and reach its maximum at a certain moment. Subsequently, its relative role will gradually diminish, giving way to fuel-fired stations and to atomic power stations. Thus, for the USA the period of a steady decrease of the share of hydropower in the power balance has already set in.

It is interesting to note that the share of hydropower in the power balance of West European countries (the USSR excluded) which was 40 per cent in 1958 is predicted to come down to approximately 26 per cent by 1975. At the same time the share of the economical water-power resources utilized, which amounts to a third at present, will increase to two thirds of all the available water resources by 1975.

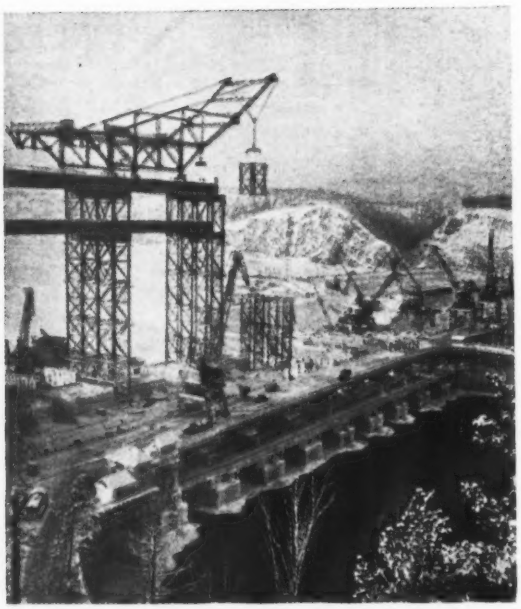
In the USSR which possesses ample and economical water power resources the share of hydropower in the country's power balance will continue to be 20 to 25 per cent.

The aggregate absolute capacity of the hydropower stations commissioned every year in the USSR is to increase steadily in the course of the coming 2-3 decades, although the electrification of the country will continue to base itself chiefly on power generated by high-performance thermal power stations.

It is important to take into consideration that the engineering conditions and economics of coal, natural gas and oil production will hardly improve with time, and will, probably, at some deposits even deteriorate due to the gradual exhaustion of the more important commercial stocks. This circumstance will also contribute to gradually enhancing the economic effect of hydropower stations.

In the conditions of a high rate of the USSR's industrial development and the consequent need for the fastest possible turnover of initial investments, the difference between the thermal and hydro-power stations, as regards capital investments per unit output and construction rates, becomes significant. That is why hydropower engineers are faced with the problem of introducing more efficient and cheaper designs of hydroengineering works and devising most efficient turbine equipment of new types (diagonal rotary-vane turbine, pump turbine, horizontal generator of the "capsule" type, etc.).

The transition to the highest form of mechaniza-



A section of the constructon site of the Bratsk Hydroelectric Station.

tion—to industrial methods in hydropower station construction—is of great importance for a number of countries. For those countries, however, that have but recently started intensive industrial development, (India among them, for instance), it is expedient gradually to introduce big-scale mechanization of the work involved in hydropower construction.

The consistent efforts towards cutting down the cost of hydropower projects have already yielded results. Thus the capital investments per unit output in hydropower projects are steadily decreasing and for new hydropower stations will be but 1.6 to 1.7 times higher (on the average throughout the country) than those in thermal power stations, even provided that the latter become considerably cheaper.

The Soviet Union possesses the world's greatest water power resources, amounting to 1,720 billion kWh of potential yearly electric power production. As much as 18 per cent of the country's total water power resources are located in the European USSR, and 82 per cent in the Asiatic part.

The significance of water power development for the growth of the power base of the Soviet economy stems from the opportunity of saving great quantities of fuel by erecting hydropower stations, the cheapness of water power in the country's eastern areas, which creates conditions for the extensive development of power-consuming industries, and the ability of many hydraulic stations to solve simultaneously the economic problems in the sphere of power engineering, water transport, irrigation, water-supply, etc.

The construction of hydropower stations in the USSR was started practically only after the Great October Socialist Revolution, when on Lenin's initiative the country's first powerful (for those days) Volkhov Hydropower Station was built.

This was followed by the erection of the Zemoavchalsk Hydropower Plant, Europe's greatest hydropower station on the Dnieper rapids, the Kondopoga Hydropower Plant, a hydropower plant on the Boz-Su canal, and many others.

An important stage in water power development in the USSR is marked by the creation of one of the world's greatest hydro-power station cascades on the Volga and Kama rivers, which, when completed, will comprise 12 big water power plants with an aggregate capacity of some 12.5 million kW generating 50 billion kW-h of electric power a year.

At present the emphasis in water power development is shifted to the Asiatic U.S.S.R., where the construction of hydropower plants of the Angara-Yenisey cascade has been started. The Irkutsk Hydropower station (0.6 million kW) on the Angara river has been built and is supplying electric power to the consumers; the Bratsk Hydropower Plant (4.5 million kW) on the Angara and the Krasnoyarsk Hydropower Plant (5 million kW) on the Yenisey are being erected at a rapid rate.

After being completed, the unique Angara-Yenisey cascade will include 10 hydropower stations with an aggregate capacity of 30 million kW, and an annual power output of some 200 billion kWh.

These exceptionally powerful, steady flow, medium and high head (40 to 300m), hydropower stations are being built in narrow rocky ranges. That is why the Siberian hydropower plants are quite cheap; the capital investments into the Angara-Yenisey power stations will, as regards the cost of one kilowatt of installed capacity, hardly differ from those into large thermal power stations.

A special place in U.S.S.R.'s water power development is held by the Soviet Republics of Central Asia, where practically all hydropower plants are economically solving the tasks of power supply and irrigation. This is quite understandable, since water in these arid areas is of primary importance for their economy. The construction of big dams and power stations (the Kairakum, Farhad, Mingechaur and other stations) on the Syr-Darya, Amu-Darya, Kura and other rivers, of water reservoirs and extensive networks of irrigation canals has permitted the farmers to raise considerably the yield of raw cotton.

The high incomes obtained from developing cotton cultivation have led to a rise in the living standards of the Uzbek, Tajik, Turkmen and Azerbaijan peoples; their everyday life has changed beyond recognition and their national cultures have advanced greatly.

Of paramount importance is the launching of the Nurek hydropower project on the Vakhsh river in the Tajik SSR, which will boost the economic development of Socialist Tajikistan. It will permit to irrigate another 1.3 million hectares of cotton land in the Republic. The conditions prevailing in the Soviet Central Asian Republics seem to be close to those in India as regards the high-efficiency in the all-round utilization of river runoffs, with priority to solving irrigation problems.

The Soviet power engineers have now attained high theoretical and engineering level in the erection of hydropower stations of all types, even in the most difficult natural conditions. Their experience of the construction of big low-head hydropower plants on affluent rivers with non-rock foundations is almost unprecedented in world practice. Soviet enterprises manufacture the unique Kaplan hydroturbines with a diameter of 9.3 metres distinguished for perfect performance, as well as other types of water turbines.

In 1959 hydropower stations in the USSR generated 47.6 billion kWh or 18 per cent of the total electric power produced in the country. The Soviet Union firmly holds the first place in Europe and the second place in the world as regards hydropower output.

The important successes scored in the U.S.S.R. in the field of power engineering within such period of time are due solely to the principles underlying the planned development of our country.

The U.S.S.R.s available water power resources are utilized to a small extent as yet only by 2.7 per cent (in 1958). That is why the prospects of water power development in the U.S.S.R. are immensely more favourable than in many other economically developed countries whose available water power has to a great extent been utilized already (France—43 per cent, Japan—52 per cent, Italy—63 per cent).

* * *

Today the utilization of river runoff is characterized by the growing co-operation of several countries which, in many cases, can only together cope with big-scale multi-purpose projects. This applies especially to those rivers that are located on the territories of several countries.

Here are some illustrations:

The Amur (Heilung Kiang) river on the border of the U.S.S.R. and China, where problems of power generation, transport, and flood control are being solved simultaneously;

The Danube river, for which a project has been elaborated, that provides for its all-round utilization in the interests of Austria, Yugoslavia, Hungary, Czechoslovakia Rumania, Bulgaria, and the U.S.S.R. A mighty cascade of hydropower plant is to be built on the Danube, the biggest of them being the Wolf's Gorge and the Iron Gates;

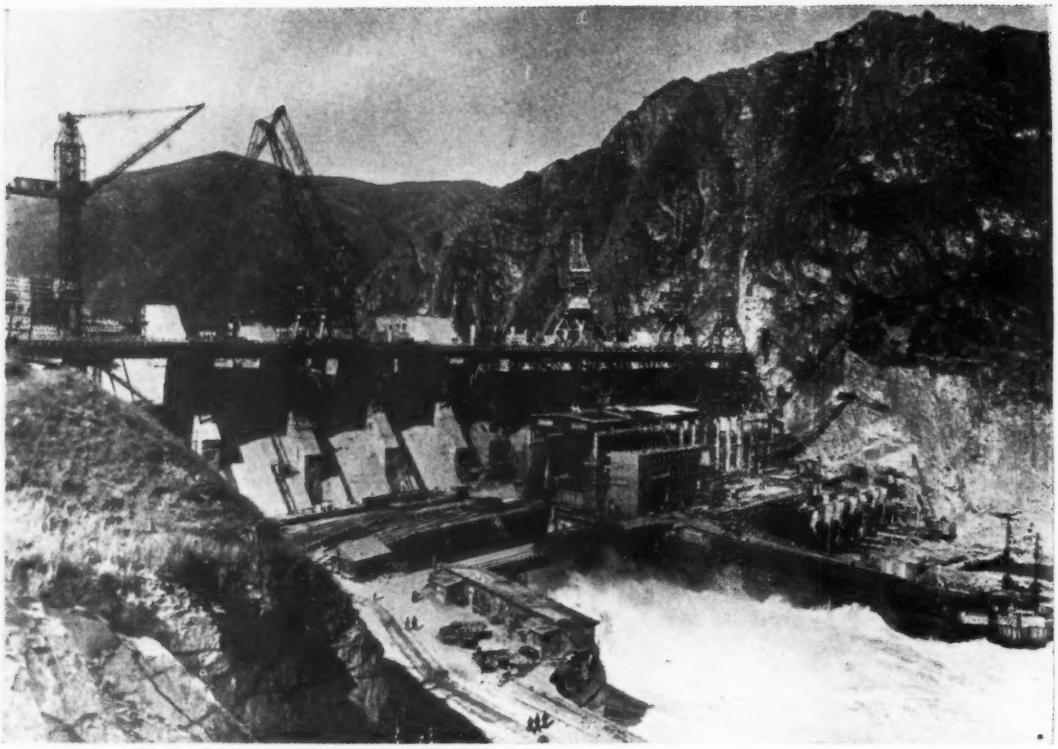
At the construction site of the Bratsk Hydroelectric Station. With the help of powerful portal cranes concrete is placed in the body of the dam.

The joint development of the power of the Paz river (Pasvikelv) which lies on the border between the U.S.S.R. and Norway and where a cascade of power stations is to be erected may serve as a good example of the beneficial economic co-operation between countries.

In due time India is bound to enter into a close and beneficial co-operation with her neighbours in the joint utilization of the runoff of the rivers that form or cross her state borders.

Some countries that have gained vast experience in water power development are rendering ever more aid to other countries which are short of such experience as yet. As an example we may cite the U.S.S.R.'s assistance in the erection for irrigation purposes of the Aswan High Dam (Assad-el-Aali) on the Nile River in Egypt with a hydropower station having a 1,000,000 kW capacity and an annual output of 10,000 million kWh of electricity.

Thus, the practice of the joint use of river runoffs by several countries is a mighty factor in bringing nations closer together and in fostering friendship among the peoples of the world through economic collaboration. Moreover, the construction of big-scale hydropower stations presents a powerful means in raising the economic potential, consolidating the political independence and in the general revival of former colonies and dependent countries, including those of the East.



General view of the construction site of the Bukhtarma Hydroelectric Station on the Irtysh River (Kazakh SSR).

It is interesting to note that way back in 1921, V. I. Lenin raised the question of engineering projects on international level.

"Projects that could serve as material foundation for international co-operation and inspire all mankind must certainly be worked out," he said. "We shall oppose the black plans of war by great plans of creative effort. Let the peoples know that great successes can be scored by joint effort in conditions of peace and friendship." These wishes of Lenin are being successfully implemented today.

* * *

It is important to solve the problems of efficient operation of hydropower stations and, especially, their cascades which are linked in respect of water economy and operate usually within complex power grids.

This calls for a systematic and careful study of the worldwide practice of running power stations. International co-operation is bound to yield positive results in this respect too.

* * *

The Soviet scientists and engineers have been consistently working on the solution of a number of fundamental scientific and engineering problems of the utilization of the river power. A basis for conducting research in the field of hydropower engineering had been established by the works of the outstanding Soviet scientists, Members of the U.S.S.R. Academy of Sciences I. G. Alexandrov, N. N. Pavlosky, G. O. Graftio, S. Y. Zhuk, B. E. Vedeneyev, A. S. Vinter, and others.

In the scientific substantiation of the prospective structure of power stations operating in the U.S.S.R.'s power grids, due consideration is taken of the fact that the water-power resources are continually being renewed by nature itself and are inexhaustible, that the use of water-power resources diminishes society's need in labour to produce fuel, that the hydropower stations are characterized by high labour productivity.

We also bear in mind that the uneven character of hydropower plant performance, due to the natural irregularity of the river runoff, is to a great degree compensated for if the hydropower stations operate in modern highly efficient power grids. The multiform functions carried out by hydropower stations in modern complex power grids are being closely studied.

We know that the economic indices of thermal

power stations are being improved today at the cost of a more complicated design and less adaptability to carrying varying electric loads. Atomic power stations are also designed to operate on a uniform cycle.

In view of this important part in carrying peak loads will be played by water power stations and, under special conditions, by pump storage stations.

The pump storage stations are regulators of electricity consumption of the highest type, capable, in addition to compensating high peak loads in the system, of creating a more efficient and economical operational duty for the parallel-functioning thermal electric stations. Moreover, the more uniform operational duty reduces the wear and tear and prolongs the service life of the equipment installed at the thermal stations.

The regulating range of pump storage stations is almost twice greater than their generating capacity. The generators of pump storage stations may be employed to raise the power factor of the grid. It is expedient to allot a part of the frequency regulation and emergency standby to the machines of power stations of this type.

A 600,000-kW pump storage hydropower station with a head of 100 m is to be constructed not far from Moscow; it will serve to enhance the flexibility and reliability of the Central Power Grid.

The growth of the Soviet engineering and economic potential and, especially, the building up of a single power grid have opened up wide opportunities for the further enlargement of the capacities of both generators and electric stations as a whole.

Natural conditions in the U.S.S.R. permit to concentrate great power capacities in hydropower stations —as high as from 5 to 10 million kW and more in a single unit; this fact corresponds well to the scope and rate of power development in the country.

Thus, exceedingly powerful generators (225,000 kW each) are being installed at the Bratsk Hydropower Station, and generators of a 510,000 kW unit capacity at the Krasnoyarsk Hydropower Station. It should be borne in mind that the Bratsk Hydropower Station will have a power capacity more than double that of U.S.A.'s most powerful Grand Coulee Station on the Columbia river, and that the capacity of the Krasnoyarsk Hydropower Station will be double that of all the 31 hydropower stations built on the Tennessee river under the TVA.

Soviet explorers have made preliminary investigations in the lower reaches of the Lena river in Siberia as to the possibility of erecting here a 20 million kW hydropower station which will transform this promising territory so rich in natural resources.

To judge by the experience gained in the U.S.S.R. and in some other socialist countries it might be expedient in the case of India to do without constructing a large number of small low-efficiency hydropower plants and to start directly erecting in favourable natural conditions big hydropower stations that are considerably cheaper.

Soviet engineers and scientists work on radical measures to reduce damage from floods resulting from water power development. This may be achieved by carefully locating the waterworks along the river, by foregoing excessive regulating capacities, by sealing off valuable lands while making water reservoirs.

It should also be noted that this problem has another aspect—the selection and preservation for future generations of the historical and archæological monuments that are in the area to be flooded. The Aswan High Dam and its water reservoir which are being built in the Nile Valley may serve as a vivid example, as the project has caused the flooding of a number of ancient structures in Egypt and Nubia. In the Soviet Union the zones to be flooded owing to the construction of hydropower station reservoirs are in all cases subjected to thorough archæological excavations and investigations.

A study is also being made of the problems involved in the joint utilization of the runoff and power of the rivers of two and more basins with different hydrological cycles. It has been shown that the joint use of the runoff of several rivers can be made by uniting directly the rivers into a single system or by parallel operation of the cascades of power stations, built in different and sometimes far removed basins.

* * *

The world contribution to the utilization of the river runoff, which has a history that goes back thousands of years, is already bringing humanity benefits on such great a scale that it is difficult to estimate them. However there are a number of countries that are only now beginning this difficult and long path.

Thus, it is evident that the peoples must ensure world peace also to bring by joint effort the energy of rivers—the source of eternal life—to the service of mankind.

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Regional Development

REGIONAL DEVELOPMENT—THE INTEGRATED DEVELOPMENT of the natural resources of a geographical unit for maximum benefit—is an idea which has received increasing attention during the past 25 years. Today, this technique, properly applied, is one of the best hopes for raising the standard of living of the countless millions of people living in the less highly developed areas of the world—a majority of the world's population.

The two outstanding examples of the success of regional development programs are the Tennessee Valley in the U.S. and India's Damodar Valley. In fact, these two valleys have served as laboratories where the concerted application of technical and managerial principles to the exploitation and control of untapped resources has resulted in large increases in the well-being of the inhabitants of the area and great benefits to the nation as a whole.

The benefits of regional development are not necessarily limited to a few areas which happen to have a combination of certain specific resources. It is not necessary to search the maps of the world looking for a country, a river valley, or a region happily blessed with a certain number of specific ingredients which, when properly prepared, result in a first-class development program. In the first place, the list of natural resources is long—water, land, minerals, population, geographical location, petroleum, and many others—and all need not be present in given quantities for successful development. Therefore, the number of areas throughout the world which are adaptable, in varying degree, to regional development is very large. And secondly, the development of a specific region not only benefits the region itself and its inhabitants, but strengthens the nation itself through the export to the rest of the country of its goods, and, more importantly, the export of its talents—the abilities of the people who have helped to make the program successful.

At the present time, most regional development programs, existing or proposed, are founded upon the control of water. The construction of multi-purpose river control structures in a particular river basin has provided the keystone which has led to the development of all of the natural resources of the region. It is to this type of program that this article is devoted.

One of the most recent examples of the planning and execution of a program for the unified development of the natural resources of a given area is the Khuzestan program now being carried out by the Government of Iran. This program, the first phases of which are now under construction, serves as an up-to-date example of regional development.

The Khuzestan region is located in southwestern Iran and is composed of the drainage basins of five rivers—Karkheh, Dez, Karun, Jarrahi, and Hindijan. The area of these basins totals 60,000 square miles of which about three-quarters are rugged mountains and one-quarter is flat plainland. Since the region has been defined as a natural unit, it includes one entire province and parts of four others. It is bounded on the west by Iraq and on the south by the Persian Gulf. It is the home of 2½ million of Iran's 20 million people.

Khuzestan contains virtually all of Iran's oil and natural gas fields and is the site of the great oil refinery at Abadan. It is the location of Korramshahr, Abadan and Bandar Shahpur, the country's only major seaports and the southern termini of the Trans-Iranian Railroad, Iran's lifeline to the outside world.

In ancient times, Khuzestan was the scene of highly developed irrigated agriculture and served as the granary for the many powerful dynasties which flourished there. In more recent days, the land has become very sparsely cultivated. Improper irrigation practices, poor drainage, and frequent floods have caused large land areas to become infertile. On the other hand, those lands remaining fertile produce very low crop yields for lack of water.

The climate of Khuzestan is generally hot and dry. Practically no rain falls during the period between May and October and summer temperatures of 45° C. are not uncommon in the plains area. During the winter months temperatures go well below freezing in the mountains and occasionally reach the freezing point in the northern part of the plains. Total annual precipitation ranges from 150 mm in the

plains to about 1200 mm (mostly snow) in the high mountains and tends to be a maximum in January.

The five rivers of Khuzestan annually discharge some 35 billion cubic meters of water into the plains. Most of this discharge occurs between December and April, often in destructive floods which inundate large areas. During the remainder of the year, water flow is low and further depleted by such irrigation as is practiced.

As may be seen, Khuzestan is well endowed with potential resources. In fact, it might be said that one of its greatest resources, petroleum, is highly developed. To some extent, this is true. The petroleum industry contributes impressive funds to the Government of Iran which are used, through the Plan Organization, for development purposes and also affords employment to a large segment of the population of Khuzestan. However, these factors are actually by-products of the development of a resource for a single purpose—the sale of petroleum—and do not represent a carefully calculated approach keyed to maximum benefits. The annual waste of vast quantities of natural gas and the sight of bare subsistence nomads within sight of the Abadan refinery attests to this fact.

Therefore, it is necessary to step back and take a broader look at the region and its resources as a whole—the rivers rushing uncontrolled to the seas, the large land areas which were once fertile but which can be restored, the oil, natural gas and other minerals, and the strategic location of Khuzestan astride Iran's gateway to the world and in close proximity to the markets of the Middle East, Asia and Africa. It is the proper consideration of all these factors upon which should be based a plan for the unified development of these resources.

In 1956, the Plan Organization of the Government of Iran requested Development and Resources Corporation, of New York, to investigate the Khuzestan region and prepare a program for the unified development of its natural resources. This company, founded by David E. Lilienthal and Gordon R. Clapp, both former chairman of TVA, immediately initiated selective surveys and investigations aimed at determining the potential of the region. These studies included the collection and evaluation of all existing data and the conduct of field operations to obtain additional information required for program planning.

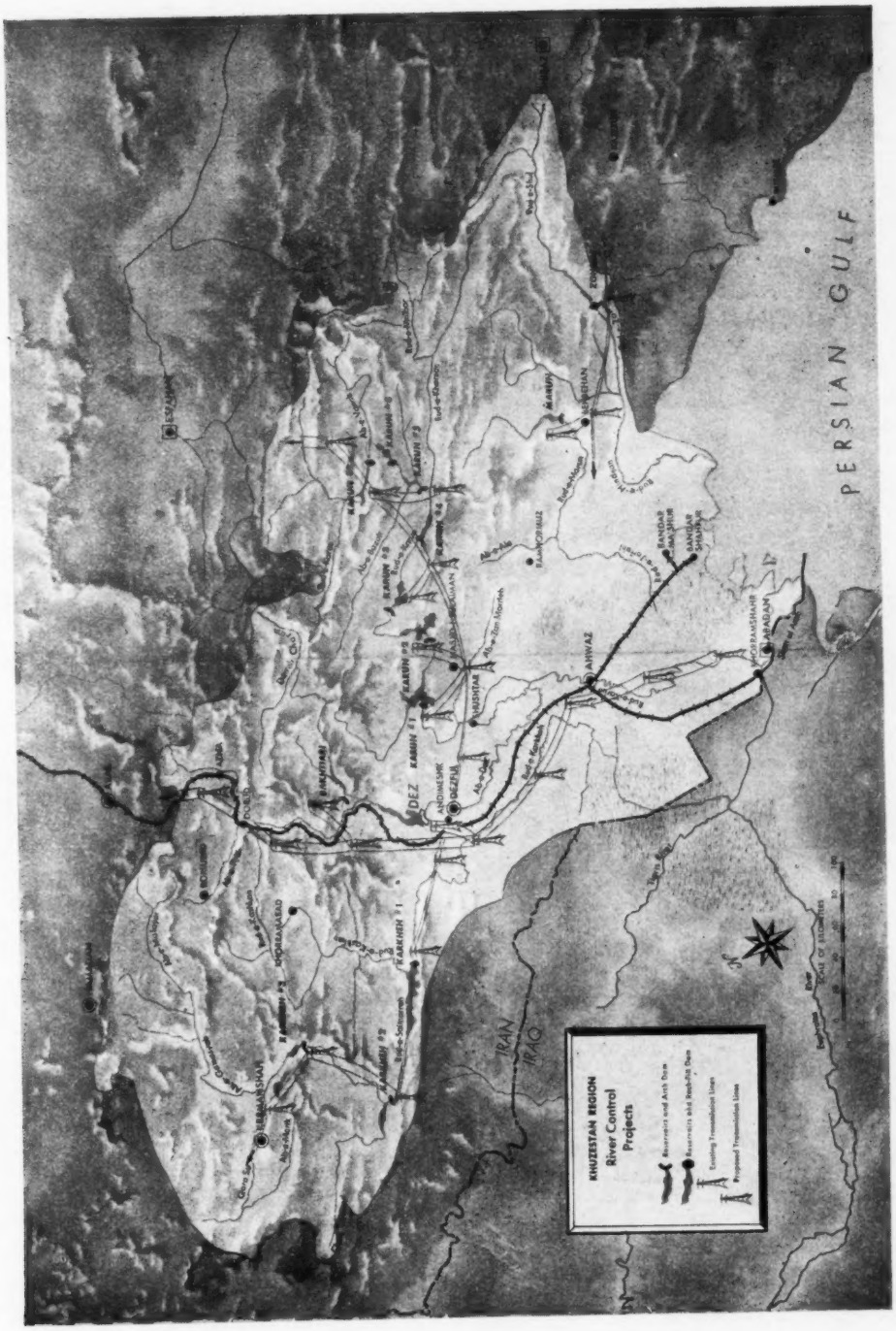
Reliable maps are essential for water resources development planning. The course and slope of rivers, the magnitude of possible dam and reservoir sites, the elevations of potentially irrigable areas and areas subject to flooding must all be known before any comprehensive multi-purpose water control plan can be formulated. This need was recognized early in the program, and a large proportion of the initial effort was devoted to the preparation of maps of selected portions of the Khuzestan region. Fortunately, aerial photographs of the entire region had been made during 1955 as a part of a national mapping program. Furthermore, horizontal control for mapping from these photographs had been established by means of Shoran, a navigational system utilizing the principles of radar. This meant that topographic maps of any areas could be prepared photogrammetrically after obtaining vertical control elevations by ground survey. Using these techniques, general topographic maps for the major rivers and more detailed maps for selected project sites were prepared. Aerial mosaics were compiled for the entire region and have proved most useful for project site location, soil surveys, land and water rights determination and other studies.

Equally vital in the planning of a river control program is the determination of the amount of water available and its present and potential uses. For this purpose, hydrological, meteorological, and water use studies are required.

Hydrological investigations cover the study of the quantities and characteristics of the water flowing in the rivers. In Khuzestan, considerable work in this field was already under way in 1956. With the assistance of technical advisers from FAO and ICA, the Hydrographic Service of Iran had initiated a program of installing stream gauging stations at strategic locations on the various Khuzestan rivers. Silt measurements at strategic locations were also conducted to determine the effect of this factor upon the life of reservoirs. The training of technicians to operate these stations and to obtain discharge measurements was an important feature of this program, as was the systematic collection and compilation of the results. This program, together with analysis of the existing streamflow data, will provide the steady flow of information necessary for program planning, project design and, later, for project operation.

Meteorological investigations for river development, closely related to hydrological investigations, are still in an early stage of development in the Khuzestan region. Only scanty rainfall data is available except at a few locations in the plains. There has been practically no rainfall and snow measurement in the high mountain headwaters and it is, therefore, impossible now to correlate precipitation with run-off—a necessity for efficient project planning and operation.

Consequently, financial and technical assistance has been provided to the Iranian Meteorological Department for the establishment of several meteorological stations in the Khuzestan mountains. Installation of snow measuring equipment was recently undertaken. However, this represents only a small start in the installation of the comprehensive network ultimately required for the systematic collection and


KHUZESTAN REGION
River Control
Projects
PERSIAN GULF
IRAN
IRAQ
DEZ
KARKHEH #1
KARKHEH #2
KARUN #1
KARUN #2
KARUN #3
KARUN #4
ANDIMESHK
DEZFUL
SHUSHTAR
AHWAZ
ABADAN
MOHAMMERAH
BANDAR SHAPUR
BANDAR MASHUR
ESFAHAN
SHIRAZ
BEHBEHAN
DOROUD
BORUJERD
KHORRAMABAD
BANDAR-E-DILAM
BANDAR-E-BUSHIRE
BANDAR-E-LENGEH
Scale of Kilometres

analysis of weather data.

Water use studies supplement hydrological studies by determining how the flow of the rivers is or may be used and how this use may be distributed among various purposes and locations. A considerable fund of information on this subject was collected by the FAO during the preparation of its 1956 report, "Development of Land and Water Resources in Khuzestan." This report has been very helpful in pointing out present patterns of water use and in describing past efforts at development by various government agencies. A systematic survey of the whole Khuzestan region is under way in order to determine present water use in all river basins. This survey, already begun with the assistance of FAO personnel, will provide the groundwork for recommendations for future water control projects, as well as suggestions for improvement in existing methods and practices.

Geological investigations in the river survey program were aimed at determining the ability of foundation rock at selected damsites to support large river control structures. Such studies range from preliminary field inspection to detailed foundation investigations, using core borings and adits. A three month inspection trip by an engineering geologist indicated that most of the selected sites were acceptable. The general information on the geology of the region was helpful in later mineral surveys.

Land investigations were aimed at gathering the information needed to establish a pattern of land use for crops, pasture and forestry that will assure the highest possible value of agricultural output, without long-run depletion of soil resources. This objective required soil surveys, to establish the physical and chemical characteristics affecting soil fertility; irrigation studies, to determine land and water rights, present water use and most profitable use of irrigation water in light of soil, climate and agricultural markets; ecological studies, to investigate the natural plant life of the region; and agronomic and fertilizer response studies, to determine optimum cropping patterns. As in the case of other investigations, these studies proceed concurrently with project action.

In addition to these, mineral and industrial surveys were carried out. The objective of investigations in this field was to determine the minerals, including waste gas, suitable for industrial use, and to develop plans for their effective exploitation, with primary emphasis on meeting the requirements of Iran's domestic market rather than exports. Future investigations in this field will emphasize specific project opportunities that could be exploited by private or public capital, separately or in combination.

Finally, economic studies were necessary to evaluate the many choices involved in the selection of various projects. These studies include cost-benefit comparisons, to rank potential projects in a timed development sequence, to assure most efficient use of Iran's resources; electrical load forecasts; agricultural-economic investigations, to help in determining optimum cropping patterns; and continuing analysis of the industrial potential of Khuzestan's mineral resources.

In March 1959, following completion of initial investigations, Development and Resources Corporation submitted to Plan Organization its report entitled, "The Unified Development of the Natural Resources of the Khuzestan Region." This report outlined the startling potentialities for development of the region. The backbone of this ultimate program is a system of fourteen major multi-purpose dams which will provide:

- — a minimum regulated flow sufficient to irrigate one million hectares of fertile land in the Khuzestan plain
- — a tremendous source of hydroelectric power—over 6.5 million kilowatts—which, properly complemented by thermal station capacity, will result in abundant, low-cost electrical energy
- — protection from periodic floods which recurrently devastate the region and render useless vast areas of land
- — reliable navigation from the Persian Gulf at least as far upstream as Ahwaz, the potential industrial capital of Khuzestan

The location of these dams is shown on Exhibit I. The lowest of these dams would be 290 feet high, the highest would be over 700 feet. In terms of power capacity, the smallest would provide 70,000 kW; the largest, 12,00,000 kW. When all 14 dams are built and fully used in the years to come, a hydro power capacity of 6,600,000 kW would be available, to operate with an estimated 3,100,000 kW of thermal capacity, also to be built. Fuel for thermal stations is abundantly available in the vast quantities of natural gas now being wasted.

The system of dams described here would produce a fourfold increase in the minimum regulated flow to the plain of Khuzestan. This means that during the driest season the best lands of the plain could be supplied with four times more water than is available now. The effect of an increased minimum flow of this magnitude is a basic index to the irrigation and agricultural development these dams would support.

The cost per kilowatt of installed power capacity, or cost of irrigation per hectare of land, when considered in light of prospective benefits, are very reasonable, although the total cost of the entire program will be very great. It should be spread over a long period of time not only because of prudent financial considerations, but also because wisdom suggests that projects actually be constructed at a pace closely related to emerging needs and to an expanding source of capital from the dynamic effects

of previous steps in the scheme. Each step toward greater productivity helps to create and mobilize the sources of capital for the next step.

Khuzestan's industrial potential is greater than any other region in the Middle East. Its plentiful petroleum reserves, tremendous hydroelectric potential, revitalized agriculture, strategic location with regard to markets, and the nucleus of a trained labor force offer boundless possibilities. Its natural gas reserves in combination with low-cost power point towards the petrochemical industry with its wide variety of processes and products. Electrometallurgical development based upon low-cost power and Khuzestan's minerals is another favourable possibility.

No attempt was made to blueprint a future industrial development program. This segment of economic activity, dependent as it is upon the decisions of thousands of business men, landowners, farmers, shopkeepers, merchants—investors all—as well as the agencies and leaders of government will unfold best if not planned rigidly. The important guiding principle is to start with the real circumstances of today and from intelligent study select the basic beginning steps that meet urgent needs—steps that are feasible and within the financial and technical capabilities of available resources.

During the course of the survey and investigation program, it became apparent that the selection of the initial steps to be undertaken was possible prior to the formulation of an overall program. Therefore, in September 1957, Plan Organization approved recommendations by Development and Resources Corporation for the initiation of several specific projects.

The program authorized at that time included:

1. Preliminary work leading to the construction of a multiple-purpose dam on the Dez River.
2. Erection of a high voltage electric transmission line between Abadan and Ahwaz.
3. Development of a 10,000-hectare irrigated sugarcane plantation, near Shush, with mill and refinery to produce 30,000 tons of refined sugar a year.

Work was immediately started on these projects while, at the same time, the development of the overall plan continued.

At the present time, the Khuzestan program has taken the following shape.

Preliminary work on the Dez Dam has been completed, the main construction contractor is on the site and completion is scheduled for late 1962. The World Bank has granted a $42 million loan for this project including its irrigation and power facilities. The dam is a double-curvature arch structure located in the narrow Dez canyon. It is 620 feet high and will impound a reservoir of 2.7 million acre-feet. Located deep within the right canyon wall is an underground powerhouse with an initial installed capacity of 130,000 kW and provision for an ultimate installation of 520,000 kW. Above the powerhouse on a ledge in the canyon wall are the control building and main power transformers. The project switchyard is located on the plateau above, some 1500 feet above the river bed. These facilities are all connected by a 3-mile-long permanent access tunnel which winds down the canyon wall. Three sluiceways are located in the dam for the purpose of releasing water for irrigation during periods when the powerhouse is shut down. Two spillway tunnels are located in the left canyon wall. River diversion during construction has been accomplished through a 50-foot-diameter diversion tunnel, completed in late 1959.

The electrical transmission system associated with the project includes the 132 kV Abadan-Ahwaz transmission line cmpleted in 1959, a 230 kV transmission line between Ahwaz and the Dez Dam now in early stages of construction, together with associated sub-transmission (down to 11 kV) and substation facilities. A 230 kV line north from the Dez Dam to Azna is tentatively scheduled for installation as soon as plans for a steel mill at Azna materialize.

Complete rehabilitation and expansion of the electrical distribution systems of several of the larger cities is being carried out so that they will be prepared to receive Dez power when it becomes available. This work was initiated in Ahwaz two years ago and in March 1959 this system received the first power transmitted over the Abadan-Ahwaz transmission line from the oil company thermal station in Abadan.

The Dez Irrigation Project will begin in a 20,000-hectare pilot area about 30 miles south of Dez Dam. Canals and other facilities are presently under design and the area will receive its first water in 1963. This area will operate for a trial period of three years, after which it is expected that a diversion dam and main canals will be constructed for the ultimate irrigation of 125,000 hectares.

The above facilities will be owned and operated by the Khuzestan Water and Power Authority, an Iranian organization now being formed which will have a broad mandate covering the distribution of water and power throughout the region. This agency will be responsible for continuing the Khuzestan Development Program through to fruition. Its predecessor, the Khuzestan Energy Authority, is now operating the Abadan-Ahwaz transmission line and providing technical and managerial assistance to the municipal power agencies.

The Khuzestan Sugar Project is located about midway between Ahwaz and the Dez Dam in a part of the ultimate Dez Irrigation Project area. This project will consist of a 10,000-hectare irrigated sugar

(Continued on page 42)

Kanwar Sain
Chairman and Administrator,
Rajasthan Canal

Are River Valley Projects Worth their Large Investments ?

RECENTLY SOME ARTICLES HAVE APPEARED IN THE press which have not done justice to the cause of river valley projects. Investments on river valley projects cannot and must not be considered purely as commercial transactions. The criterion of calculating percentage of return from direct revenues as laid down by the British Parliament almost a hundred years ago no longer holds good. This was based entirely on capitalistic economy and had been specially evolved for India under the British rule. No. other Government ever accepted this criterion. Certainly in the Independent India of socialistic pattern it can have no place. In the United States various studies developed a criterion on the basis of benefit-cost ratio. A number of empirical and theoretical studies on the subject have been made on benefit-cost calculations in connection with the river valley projects. A statisfactory solution of these difficult problems, however, still seems to escape us.

Financial and Planning authorities, particularly in under-developed countries with limited resources, are naturally keen to know suitable investment criteria designed to permit a rational judgment on the allocation of the limited resources between different sectors of development. Such criteria would have to throw light on the so far unsolved questions of national economic planning that are related to the ranking of river valley projects with other social overhead investments, the determination of the relative public expenditure level, the allocation of costs to the different and yet joint purposes of the project and the consideration of subsidiary investments which would secure the prompt and optimum use of the new capital goods and services. This would postulate adequate and comprehensive knowledge of not only the actual but also potential factors of the various components of river valley projects.

Perhaps the first and the most important consideration is that river valley projects must be viewed in their relation to the total economic and development plan of the country under consideration. As pointed out by Mr. K. William Kapp of Brooklyn College, "what is relevant in this connection must be determined in each case by the effect and potency of an impulse (such as irrigation and power) to bring about changes in the social system in the direction of cumulative expansion." A complete quantitative and truly scientific assessment would be quite complex. It would, however, be helpful if the relevant and strategic functional relationship which river valley projects are likely to set in motion can be determined and identified. The planners must know the effects which a given supply of water in a dry area may have on the structure of farm production, and what will be the effect of the new structure of production on the rural subsistence economy. Supply of water alone may not ensure optimum utilisation of the new capital resource. It will be necessary to determine what administrative arrangements and subsidiary investments will be called for in the public and the private sector to assure the optimum utilisation of the water brought in the area, and through it the maximum advance of the region.

In any case it is the test of increased productivity which must provide the most comprehensive and the major test in assessing whether a certain river valley project deserves allocation out of the limited resources in an under-developed country for several competing objectives.

The Four Factors

India's whole development effort must be viewed against the background of four somewhat inter-related factors which define her present economic position, that is (i) recurrent acute food shortages (ii) extreme poverty of great masses of the population (iii) rapid population growth (iv) unemployment as well as under-employment.

Out of these four factors, the position regarding the other three will be reflected in the first factor. It is this factor which should determine the distribution of the limited resources in the field of development.

Between 1948-53 India imported 19.3 million tons of cereals. The average annual food shortage was 3.2 million tons. At an average cost of about Rs. 450/- per ton, the total cost in foreign exchange requirements due to food shortage amount to Rs. 1.5 billion. In the absence of foreign assistance, the prevention of general starvation and famines for large masses of the population depends upon the country's ability to increase the output of food. Recurrent shortfalls of food are a threat even to the implementation of the industrialisation effort.

It is true that the production of food can be increased either (a) by improved techniques of production of land already under cultivation or (b) by expanding the area under cultivation. It must be appreciated, however, that further improvements of techniques through greater use of fertilisers, farm equipment and improved seeds depend for their success upon an assured supply of water. There appears to be little doubt that the only dependable way of establishing a system of intensive agriculture as well as of extending the margin of extensive cultivation seems to be to provide areas with a low and uneven rainfall with assured water supply. This can be done only by storing the run-off in catchment areas which have an abundant rainfall and diverting this dependable supply of water through canals and distributaries to the areas with inadequate and variable rainfall. This is precisely what the river valley projects in India are attempting to do. This is what responsible and wise rulers in the past seem to have done in India since times immemorial. The scope and dimensions of such structures have naturally varied in accordance with the technical knowledge and the resources available to them.

The direct benefits accruing from a change by providing irrigation can be assessed by a study of the practices prior to the introduction of irrigation and the actual results obtained in similar areas on the introduction of irrigation. A valuable study in this respect has been made by Mr. K. William Kapp in his valuable Paper "River Valley Projects of India: Their Direct Effects" and need not be repeated here as the results are fairly well known to students of agriculture and irrigation as well as the revenue authorities in India. Such assessment from the data available from revenue papers or farm accounts for the past years suffers from one major fault.

Blame for Non-Utlisation analysed

There has been a general criticism that the potential created by the river valley projects in the past ten years has not been fully used. The blame for this must not be laid at the door of the river valley projects or those who are responsible for planning and constructing them, but on the fact that for the most part there was no deliberate plan for many of the subsidiary investments and administrative steps which must be taken in order to make the fullest possible use of the water resources made available by these river valley projects. The policy generally pursued even in recent years has been that of relative *laissez-faire* as followed previously under the British regime. It was left to the individual cultivator to make the necessary adaptation to the new techniques of agriculture called for by the perennial supply of water. The cultivators were often either ignorant or suspicious at least during the initial stages of the introduction of the new method of cultivation called for by irrigation. They were not helped by demonstration farms which could give them the necessary confidence. Even those who needed no persuation did not have adequate funds required for such subsidiary investments as the purchase of good bullocks, fertilisers, improved ploughs and seeds, more and better food-stuffs for draft animals used for longer periods of time etc.

Two Examples

Experience in the development of the Thal Desert in Pakistan led the Pakistan Government to establish Thal Development Authority for the overall development of the area simultaneously with the completion of the Thal Canal Project. Most of the reclamation and levelling work was carried out mechanically by the agricultural machinery organisation which operated a fleet of imported equipment worth 32 million $ (US). Construction of 38,000 out of the total of 55,000 rural houses had been undertaken by the Thal Development Authority. Whole towns were built by the Authority. Even industries like textile and sugar were undertaken by the Authority. When a settler came to live in the Thal desert, he need not possess any capital. He gets loans from the Thal Development Authority which he pays in easy instalments spread over 35 years. He gets taqavi loans for the purchase of draft animals, implements, seeds and manure and pays back in instalments spread over 10 years. Apart from the price of the land which is reckoned at Rs. 150 per acre, the total value of the taqavi loans given to him in different shapes usually amount to Rs. 1,200. It is also customary to give a settler enough grain to live on till he gathers his own harvest.

Egypt has followed similar procedure for the development of its desert areas. The reclamation programme in Egypt is co-ordinated with settlement programme by migrating persons from over-crowded areas to the newly reclaimed areas. In two villages which we saw in March during our visit, houses of standard plans had been constructed for the settlers by the Government. Besides residential accommodation, social amenities like the mosque, primary school with a theatre hall, a clinic, a co-operative store and staff quarters for teachers, medical and other co-operative staff were built by Government. As

the settlers are chosen from landless poor families, each family was given transportation charges, food including tea and sugar, furniture, a cow, 20 chickens and a loan of £5 for initial expenditure. All the expense is paid back by the settler in suitable easy instalments. Facilities provided to settlers in Israel are even much more liberal.

The Planning Commission in the Draft Outline of the Third Five Year Plan,have emphasised that developmental activities allied to water resource development projects should be carried out by the State Governments simultaneously. It must, however, be emphasised that in helping landless labourers to settle in a desert newly provided with irrigation facilities, considerable loans will have to be given to each family. Entire villages with community amenities will have to be constructed by Government unless we are prepared to create further slums in such new areas. Unless the minimum expenditure on such allied development is incurred by Government, there should be no surprise if utilisation of irrigation waters considerably lags behind the potential created by irrigation works.

At this stage I may also refer to another bogy raised by the former Census Commissioner, i.e., the possibility of diminishing return from additional irrigation projects. It has been argued that future irrigation projects are bound to be not only more expensive but less productive than those built in the past. Ultimately the answer to this question depends not only upon the ability to take into consideration the effects of evolving improvements of farm techniques but also on the food requirements of the rising population. As pointed out by Mr. William Kapp, 'diminishing returns is a concept that comes to us from the static framework of classical and neo-classical economists.' The dynamic change and technical improvements are the factors which have counteracted the static phenomenon of diminishing returns in the past. Such static considerations of economists of the old school must not be permitted to play havoc with the future food requirements of the increasing population.

The family planning efforts have been started rather late to show any results before the population will have almost doubled. Current estimates place the rate of population in India at 1.9% per annum as against earlier estimates of 1.2 to 1.5%. To meet the food requirements of the additional population, food production must be increased by a big percentage. No conceivable programme of imports or rationing can meet the anticipated gap between the requirements of increased population and the present level of food production. Improved methods of cultivation alone are unlikely to be sufficient to cover the food deficit. In India the deficit can be eliminated only by transforming the unproductive and sub-marginal lands into productive areas. This can be done in a big way only by providing irrigation facilities by the construction of river valley projects which inevitably require large expenditure.

The Rationale of River Valley Projects

Undoubtedly projects for the development of water resources for an entire river valley are major capital investments. Their most important objective is to set in motion a cumulative process of growth by providing the region with the productive factors which are in short supply, i.e. water and power and in some instances, navigation facilities and control of floods. Viewed from this angle, river valley projects have many characteristics in common with the general economic planning of which indeed they are an integral part. Like a general economic plan. a river basin development project must be understood to be much more than a simple decision to increase the rate of capital formation in a given year. It is a programme of strategy, a deliberate state interference to assure that the process of circular interaction really comes off and develops as planned.

Many people including some press correspondents, economists, administrators and politicians fail to appreciate the full implications of these interactions. It has become almost a fashion to highlight small weaknesses in planning and execution, ignoring the huge benefits which river valley projects bring in train after them. Such a picture though buttressed as it might be by extracts from audit reports torn out of context would not be the truth. If one said that Karl Marx suffered from boils, that Cromwell had a big wart on his nose, that Bonaparte was a victim of epilepsy, that Lenin was bald, that would be saying true things but if that was all one said about these men it would amount to telling monstrous lies. To stress the minor weaknesses of a big project and to ignore the very thing for which the project was conceived and constructed would be a criminal lie.

In the first place a long term investment project cannot be expected to be remunerative in the short run. Indeed if it had been remunerative in the short-run, there would be no reason why it should not have been undertaken by private enterprise or local bodies. The heavy initial outlays required, the long term and social character of its benefits, the uncertainty of its outcome and the fact that the emergence of even the tangible direct benefits depends upon a whole series of subsidiary organisational measures and joint investments, has been responsible for the lack of interest of private enterprise in these projects.

Secondly, whether we wish to refer to river basin projects as public works or as social overhead investments, or whether we stress their effects in bringing about an extension of markets and hence of the division of labour or whether we emphasise their effects in terms of 'external economies', the planning autho-

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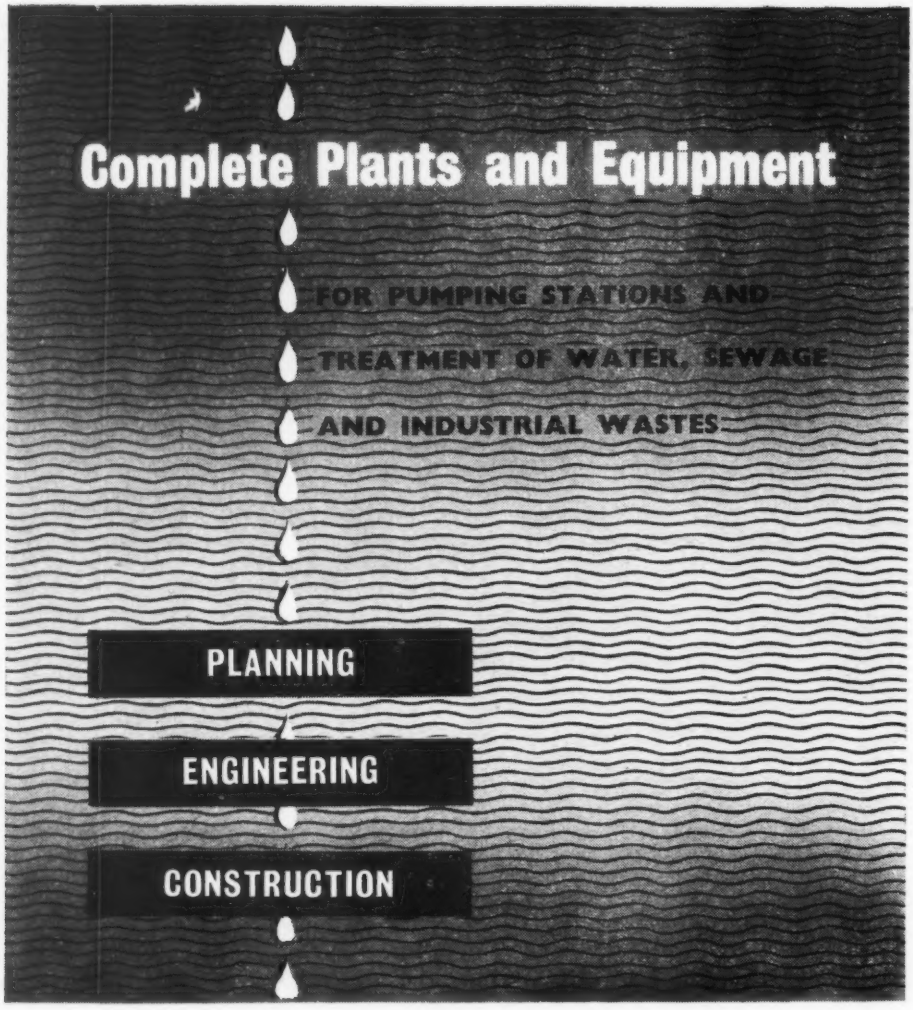

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SISTA'S-EE-74

Leut. Gen. E. C. Itschner
Chief of Engineers, United States Army

U. S. Army Corps of Engineers Water Resource and Power Projects

THE HYDROELECTRIC POWER RESOURCES OF THE UNITED States have been developed extensively, particularly in recent years, and constitute a significant portion of the electric power capacity of the nation. Of the total installed generating capacity of 174 million kW at the end of 1959, 18 per cent is in hydroelectric plants. Of this amount, over one-half has been developed by private or non-Federal public utilities and the remainder developed by various agencies of the Federal Government in conjunction with the Federal water resource activities involving navigation, flood control, irrigation and related purposes.

Non-Federal hydroelectric power projects affecting navigable waters of the United States, which waters include the principal river systems, are developed in conformance with the Federal Power Act, administered by the Federal Power Commission.

Federal hydroelectric projects are developed in accordance with laws applicable to the other water resource activities of the Federal Government. This involves primarily three Federal agencies: (1) the Tennessee Valley Authority, which constructs and operates power and multiple-purpose projects and markets power in the Tennessee Valley and adjoining area; (2) the Department of the Interior, which constructs and operates projects for irrigation and related purposes in the Western United States and acts as the power marketing agent for its own projects as well as for those of the Corps of Engineers; and (3) the Army's Corps of Engineers, which constructs and operates projects for navigation, flood control and related purposes on a nationwide basis.

The purpose of this article is to describe and summarize this third category of Federal water resource and power development, which is known as the Civil Works Programme of the Corps of Engineers.

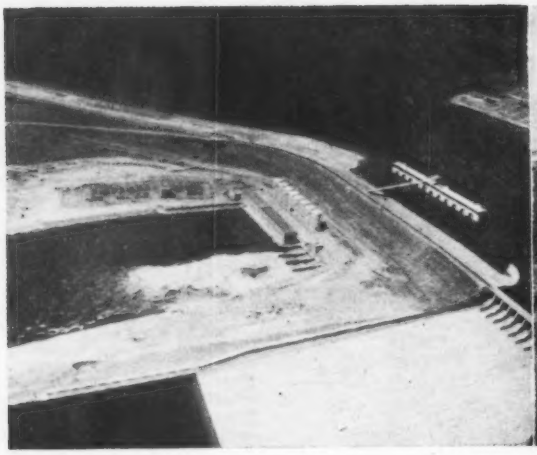
The activities of the Corps of Engineers in this field had their origin in the Federal interest under the Constitution for regulation of commerce on the navigable waters of the United States. In the early 1800's the Corps was assigned the first Federal improvements for navigation. In the 1850's flood control on the lower Mississippi River also became a matter of Federal concern, and the Corps instituted a series of measures which led to the development of a comprehensive flood control plan in 1928. At this time also the Corps of Engineers was directed to prepare comprehensive general plans for use of all of the nation's principal rivers with a view to utilization of their resources for navigation, flood control, irrigation and hydroelectric power. These plans, known as the "308" reports, constituted the initial framework for modern, multiple-purpose planning and development of the nation's water resources. For example, the Tennessee Valley programme was an outgrowth of this series of reports.

The "308" reports also formed the initial basis for the first nationwide legislative authority, granted to the Corps of Engineers in 1936, 1938, and 1944, for comprehensive flood control and multiple-use planning and development including power, water-supply and related purposes.

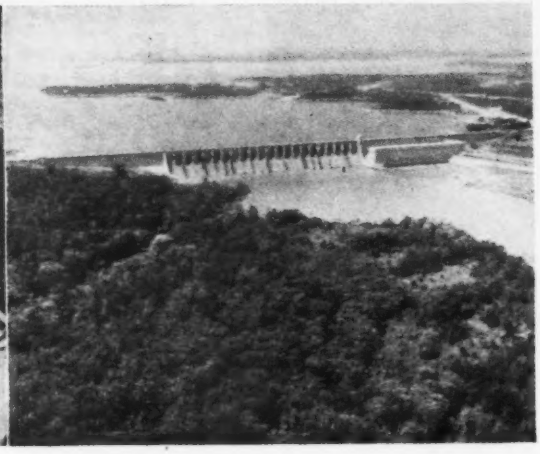
Under these authorities, the Civil Works programme of the Corps has grown steadily to meet national requirements for use of its water resources. There are now about 3,300 projects in operation, ranging from dredged channels solely for navigation to large, complex multiple-purpose projects and systems for all water uses.

We now have more than 22,000 miles of improved waterways, some 500 harbours, local flood protection for over 300 localities plus provision for regulation of flood flows in more than 100 reservoirs. Some of these reservoirs also provide water supplies in excess of 400 billion gallons annually for 40 communities and have 4 million acre-feet of storage space for irrigation. In recent years the use of these multiple-purpose reservoirs for recreational purposes has approached 100 million visitor-days annually.

The first Corps of Engineers project to include hydroelectric power was Wilson Dam, completed in 1925 and subsequently incorporated into the Tennessee Valley programme. There are now over 6



Downstream side of the Army Engineers new Fort Randall Dam. Portion of the huge reinforced-concrete spillway below. Outlet works, powerhouse, surge tanks and switchyard beyond. The partially submerged structure connected to the embankment by a service bridge is the intake or upstream entrance to the twelve tunnels (eight power—four flood control) which carry Missouri River flows through the dam.



John H. Kerr Dam, on the Roanoke River, Virginia and North Carolina.

million kilowatts of generating capacity installed in 32 Corps projects and additional capacity of 4 million kilowatts is under construction. A summary of data on the projects involving hydroelectric power is shown at the end of this article.

The Civil Works programme of the Corps of Engineers is carried out in accordance with specific directives from the Congress. Surveys and studies of river basins or individual projects are authorized by acts of the Congress or resolutions of its Public Works Committees. The survey plans and estimates are prepared by one of the Corps' District offices, reviewed by the Board of Engineers for Rivers and Harbours, and submitted to Congress with the recommendations of the Chief of Engineers and the comments of other Federal agencies and the States. After projects are approved and authorized by the Congress, funds are requested annually for detailed planning and construction as part of the public works programme proposed each year by the President.

The planning and development of the various aspects of the Civil Works programme is carried out by 40 district offices of the Corps of Engineers. The boundaries of areas which these district offices handle correspond generally to the drainage basins of our major river systems to assure a unified comprehensive approach to river basin development. The district offices are under the general supervision of 11 division offices, and of the Chief of Engineers located in Washington, D.C. There are some 27,000 engineers and other civilian employees and approximately 100 military personnel of the Army employed in this organization on Civil Works activities. This highly qualified and organized force can be quickly shifted from civil to military lines of endeavour, a circumstance which greatly reduces the difficulties of mobilizing engineers for an emergency.

Most of the planning and design of the Corps of Engineers is handled by the district office staff. When workload demands however, planning is also contracted to reputable architect-engineer firms. Actual construction of projects of this type is handled by contract under the supervision and inspection of the district offices.

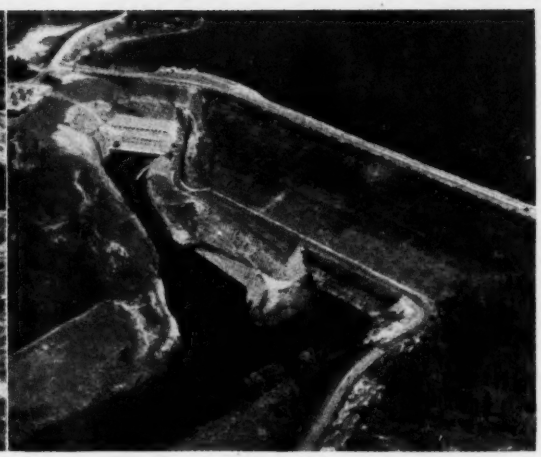
Planning of water resources projects is co-ordinated throughout its various stages with other state and Federal agencies concerned with water resource development, and the assistance of the Federal Power Commission is of particular importance where power is involved. Power generated at Corps projects is turned over to the Department of the Interior for disposition. Four marketing agencies which have been established within the Department of the Interior handle the actual sale of the power. All costs fairly allocated to power are returned to the Federal treasury over a period of years from power revenues.

The accompanying tabulation lists only those projects of the Corps of Engineers which include power generating facilities. Most of these projects are units of an overall co-ordinated plan designed for the comprehensive development of an entire river system for all beneficial uses.

Southern and South-Western Rivers

Throughout what are known as the southern and south-western states the development of such comprehensive plans is underway. River systems on which work has been started include the Roanoke, Savannah, Chattahoochee, Alabama-Coosa, Cumberland, Neches-Angelina, Brazos, Arkhansas, Red and White.

Overall aerial view of Garrison Dam, Missouri River, taken from position over west abutment. Foreground, right, surge tanks and powerplant; tailrace. Left, intake structure. Across dam, right, spillway and stilling basin. Far left, Government town of Riverdale, North Dakota.



Buford Dam, Chattahoochee River, Georgia.

More or less typical of these systems is the series of projects on the Chattahoochee River. By means of three low-head dams, and dredging and snagging in portions of the river, a 9-foot canalized waterway is being opened from the Gulf Intercoastal Waterway some 268 miles inland. In the upper reaches of the river the large Buford storage project has been constructed and provides the regulation of flow necessary to maintain this channel. Power plants are included in three of the dams to utilize the regulated flow. In addition, flood storage space is provided at Buford for protection of low-lying lands below that reservoir.

An interesting aspect of the Corps' programme is demonstrated in the development of the Roanoke river. The crops devised a plan for the Roanoke which contemplated the complete development of the river by a system of 12 reservoir projects. The largest and key unit of this system, the John H. Kerr project, was constructed as a Federal project for multiple uses. Private power interests have since constructed one of the other units in the plan, and are planning to build several others. This is one of many instances where the Corps' comprehensive plan has provided a framework upon which optimum reservoir basin development can be achieved, even though different agencies construct and operate the various components of the plan.

Columbia River Basin

In the north-western part of the United States the entire 259,000 square mile drainage plan basin of the Columbia River and its tributaries has been considered in developing a unified co-ordinated plan to achieve the best results. Over half of the generating capacity in operation or being installed by the Corps of Engineers is located in this basin. Although the power potential of the Columbia is so great that it somewhat overshadows other aspects, the river poses many water problems and also presents many opportunities for improvement for other purposes.

The comprehensive plan involves the capture in upstream storage reservoirs of excess runoff that comes every year with the spring snow melt, and the release of the stored water progressively through the system of dams and reservoirs downstream, when needed throughout the year.

Retention of the spring runoff in upstream and tributary reservoirs alleviates a very serious flood problem on the lower Columbia River. The resulting regulated flow is subsequently utilized through turbines and locks. The canalization of the river as planned will eventually extend barge navigation deep into the heart of the region. Some of the stored water will also be used for irrigation. The upstream and downstream passage of migratory fish and the effects of reservoirs on their spawning and survival are principal areas of concern. The regulated flows released from storage are used and re-used through a series of power plants downstream, making possible the generation of large amounts of power at a cost lower than that for any comparable region in the country. Availability of this low-cost power has been one of the principal stimulants to the rapid growth the North-West has experienced. Projects are generally designed with an initial installed generating capacity greater than that required to produce firm power. This excess power is available at all times except during the infrequent years of extremely low flow and is offered to customers at favourable rates.

The Columbia River and tributaries system of development is unique in several ways. The highest annual runoff occurs regularly in the late spring and early summer. This allows the same reservoir space

to be utilized jointly for flood control and other flow regulation purposes. The predictability of the high runoff and the provision of storage above the run-of-river hydroelectric facilities adds power benefits by co-ordinated operation that would not otherwise be possible. This operation consists of capturing a large part of the flow in reservoirs during the flood periods and operating run-of-river power facilities at full capability during this period from runoff available from the uncontrolled area and reservoir spills. Provisions are usually made in the initial construction for additional hydropower units to be added in the future, when they can be utilized to meet the load.

The headwaters of the Columbia River and some of its tributaries are in Canada. The development of the headwaters to the mutual benefit of Canada and the United States is presently under discussion with a view to international agreement concerning the sharing of the benefits and costs involved.

Missouri River Basin

The basin-wide approach has also been taken in the development of the Missouri River, which drains a large area in ten Western and North Central States. The Corps is constructing six main-stem reservoirs as an essential part of an overall basin programme of projects for multiple uses. The six projects, most of which are already in service, include several of the largest earth-fill dams ever built, and have enough storage capacity to store two and two-thirds times the total average annual flow of the Missouri River at the downstream dam. The storage capacity is provided in operational zones; that is, (1) exclusive flood use space, (2) a reserved annual use space, and (3) dead storage for head and for sediment retention. The reserved annual use space is for retention of flood flows and for subsequent release for other project purposes, principally navigation, power and irrigation. Flood control by reservoirs located in the upper main stem of the river is supplemented by levees for the protection of downstream areas.

Planning these projects involved considerable study to estimate the depletions of water-supply due to diversions and consumptive uses, and to determine the effect of these depletions on other multiple-purpose uses, such as navigation, water-supply and power. Another important planning factor was the rate of degradation and aggradation and the estimation of their effects on tail-water and reservoir conditions at each project. The results of these studies were also used in selecting the settings for the turbines.

Each of the six main stem projects on the Missouri embraces power generation facilities. The regulated releases for navigation usage assure an adequate supply of water for power to meet the summer load requirements, which are now greater than the winter load requirements in some parts of the region due largely to the power used in air conditioning. A transmission grid of over 7,000 miles is provided so that power can be delivered to customers. The power from the six main-stem reservoirs is being marketed by the U.S. Bureau of Reclamation in conjunction with the power produced at other Federal plants operated by the Bureau in the Missouri River Basin.

McNary Dam, Columbia River, Oregon and Washington, showing navigation lock on Washington shore in lower left foreground. Eight 70,000 kW generators are now on the line.

Comprehensive aerial view of Fort Peck Dam on Missouri River in Montana. Four-mile-long dike marked by white line. Left foreground, town of Fort Peck. Left at end of Dam, powerhouse and scene of work on second powerplant. Across dam at right, intake structures and far right from end of dam, mile-long spillway. Fort Peck, begun in 1933, is completed except for second powerplant. The latter is 60 per cent completed and will go into service in 1961. Both Garrison and Fort Peck dams are now key units in the Pick-Sloan program of Missouri River Development by the Corps of Engineers.

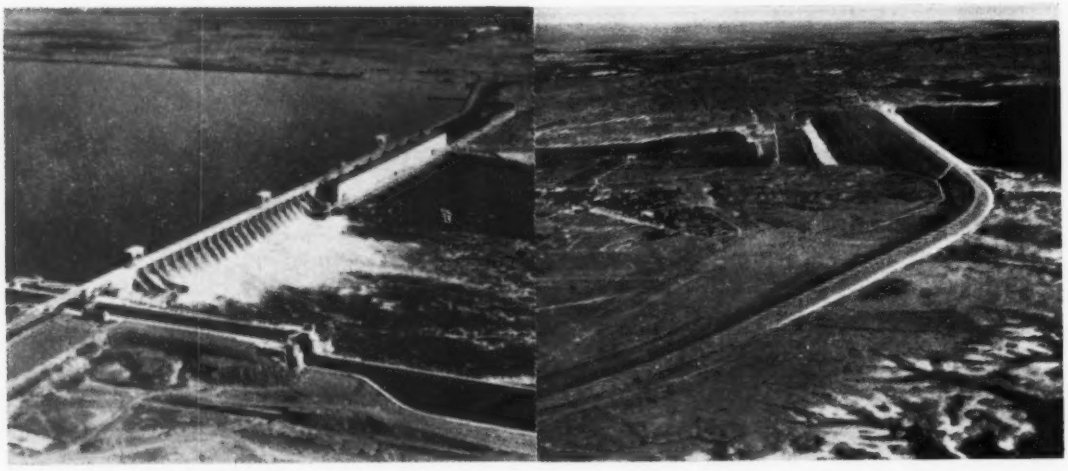
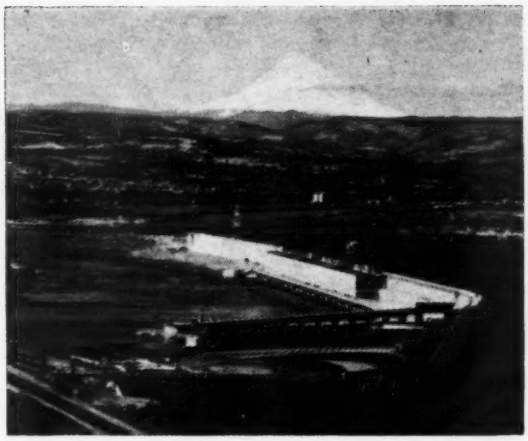


TABLE I

MULTIPLE-PURPOSE PROJECTS WITH POWER

PROJECT	RIVER	DRAINAGE AREA	NAME PLATE RATING			AV. ANNUAL GENERATION	TOP OF POOL		GROSS HEAD(a)	STORAGE			RES. AREA	SPILLWAY ELEVATION	
			In Oper.	Under Constr.	Ultimate		Fl.Contr. Elev.	Usable Elev.		Exclusive Fl.Control	Usable	Dead	At Usable Elevation		
		Sq. Mi.	MW	MW	MW	MWH (Init)			Ft.	1000 AF	1000 AF	1000 AF	1000's Acres	Crest	Top Gates
COLUMBIA RIVER BASIN															
1. Bonneville	Columbia	240,000	518.4	-	518.4	4,550,000	74.0	74.0	58	0	Pondage	430	20.5	24.0	74.0
2. Detroit (b)	N.Santiam	438	118.0(b)	-	118.0(b)	465,000(b)	1569.0	1564.0	371	17	323(c)	115	3.5	1541.0	1572.0
3. McNary	Columbia	215,000	980.0	-	1400.0	6,140,000	340.0	340.0	75	0	Pondage	1,115	38.8	291.0	342.8
4. Lookout Point(b)	Willamette	991	135.0(b)	-	135.0(b)	373,400(b)	929.0	926.0	233	13	336(c)	107	4.3	887.5	929.0
5. Albeni Falls	Pend Oreille	24,200	42.6	-	42.6	219,000	2062.5	2062.5	29	0	1,153(c)	389	94.6	2033.0	2065.0
6. Chief Joseph	Columbia	75,000	1024.0	-	1728.0	6,487,000	946.0	946.0	171	0	Pondage	473	7.8	901.5	946.0
7. The Dalles	Columbia	237,000	963.0	156.0	1743.0	7,440,000	160.0	160.0	86	0	Pondage	277	11.2	121.0	162.0
8. Cougar	McKenzie	210	-	25.0	60.0	146,900	1699.0	1690.0	433	11	154(c)	54	1.2	1656.75	1700.25
9. Hills Creek	Willamette	389	-	30.0	30.0	166,580	1543.0	1543.0	319	0	249(c)	107	2.7	1495.5	1544.0
10. Ice Harbor	Snake	109,000	-	270.0	540.0	1,840,000	440.0	440.0	100	0	Pondage	335	9.2	391.0	442.0
11. John Day	Columbia	226,000	-	1080.0	2700.0	8,000,000	268.0	265.0	105	150	Pondage(c)	1,990	52.0	210.0	268.5
Total Columbia Basin			3781.0	1561.0	9015.0	35,827,880				191	2,215	5,442			
MISSOURI RIVER															
1. Ft. Peck	Missouri	57,725	85.0	30.0	165.0	979,000	2250.0	2246.0	212	1,000	13,900(c)	4,500	237.0	2225.0	2250.0
2. Ft. Randall	Missouri	262,150	320.0	-	320.0	1,633,000	1375.0	1365.0	128	900	3,800(c)	1,400	102.0	1346.0	1375.0
3. Garrison	Missouri	180,900	400.0	-	400.0	1,966,000	1854.0	1850.0	170	1,600	15,000(c)	4,900	390.0	1825.0	1854.0
4. Gavins Point	Missouri	279,480	100.0	-	100.0	531,000	1210.0	1208.0	41	64	321(c)	156	31.1	1180.0	1210.0
5. Oahe	Missouri	243,490	-	595.0	595.0	2,455,000	1620.0	1617.0	190	1,100	17,000(c)	5,500	358.1	1596.5	1620.0
6. Big Bend	Missouri	249,330	-	468.0	468.0	985,000	1423.0	1420.0	69	175	260(c)	1,465	55.8	1385.0	1423.0
Total Missouri River			905.0	1163.0	2048.0	8,549,000				4,839	55,281	17,921			
SOUTHWESTERN															
1. Norfork	N. Fork	1,806	70.0	-	140.0	195,000	530.0	552.0	174	732	707	544	22.0	552.0	580.0
2. Denison	Red	39,719	70.0	-	175.0	267,000	640.0	617.0	108	2,694	1,730	1,129	93.1	640.0	None
3. Narrows	L.Missouri	237	17.0	-	25.5	28,400	563.0	548.0	145	128	202	78	7.2	563.0	None
4. Bull Shoals	White	6,036	160.0	90.0	340.0	647,000	695.0	654.0	198	2,360	2,034	964	45.4	667.0	695.0
5. Ft. Gibson	Grand	12,492	45.0	-	67.5	190,500	582.0	554.0	61	922	Pondage	311	19.1	547.0	582.0
6. Whitney	Brazos	17,656	30.0	-	30.0	82,141	571.0	520.0	89	1,630	132	255	15.8	533.0	571.0
7. Tenkiller Ferry	Illinois	1,610	34.0	-	34.0	114,500	667.0	630.0	142	600	345	285	12.5	642.0	667.0
8. Blakely Mountain	Ouachita	1,105	75.0	-	75.0	156,000	592.0	578.0	131	617	1,236	665	40.1	592.0	None
9. Table Rock	White	4,020	100.0	100.0	200.0	493,000	931.0	915.0	204	760	1,932	770	43.1	896.0	933.0
10. Greers Ferry	Little Red	1,146	-	96.0	96.0	189,000	487.0	461.0	134	934	716	1,194	31.5	453.0	489.0
11. Eufaula	Canadian	47,552	-	90.0	90.0	317,000	597.0	585.0	81	1,470	1,481	897	102.0	565.0	597.0
12. Dardanelle	Arkansas	153,704	-	124.0	124.0	644,000	338.0	338.0	48	0	Pondage	430	37.0	300.0	339.0
13. McGee Bend	Angelina	3,453	-	52.0	52.0	118,400	173.0	164.0	69	1,149	1,383	1,509	114.5	176.0	None
14. Beaver	White	1,186	-	112.0	112.0	170,000	1130.0	1120.0	190	309	1,096	556	28.2	1093.0	1130.0
Total Southwestern			601.0	664.0	1561.0	3,611,941				14,305	13,094	9,786			
SOUTHEASTERN															
1. Dale Hollow	Obey	935	54.0	-	54.0	127,000	663.0	651.0	136	353	496	857	27.7	651.0	663.0
2. Allatoona	Etowah	1,110	74.0	-	110.0	169,000	860.0	840.0	146	303	285	83	11.9	835.0	860.0
3. Center Hill	Caney Fork	2,295	135.0	-	135.0	351,000	685.0	648.0	162	762	492	838	18.2	648.0	685.0
4. Wolf Creek	Cumberland	5,810	270.0	-	270.0	867,000	750.0	723.0	162	2,094	2,142	1,853	50.2	723.0	760.0
5. John H. Kerr	Roanoke	7,800	204.0	-	204.0	438,000	320.0	300.0	91	1,273	1,046	484	48.9	288.0	320.0
6. Clark Hill	Savannah	6,144	280.0	-	280.0	698,000	335.0	330.0	139	390	1,340	1,170	71.1	300.0	335.0
7. Pailpott	Smith	212	14.0	-	14.0	25,400	985.0	974.0	153	34	111	56	2.9	935.0	None
8. Jim Woodruff	Chattahoochee	17,150	30.0	-	30.0	220,000	77.0	77.0	25	0	Pondage	331	36.0	48.0	78.5
9. Old Hickory	Cumberland	11,620	100.0	-	100.0	420,000	445.0	445.0	46	0	Pondage	357	22.5	406.0	447.0
10. Buford	Chattahoochee	1,040	86.0	-	86.0	170,000	1085.0	1070.0	148	637	1,049	363	38.0	1085.0	None
11. Cheatham	Cumberland	14,070	24.0	12.0	36.0	160,000	335.0	335.0	22	0	Pondage	84	7.5	359.0	386.0
12. Hartwell	Savannah	2,088	-	264.0	330.0	453,000	665.0	660.0	130	295	1,427	1,135	56.4	630.0	665.0
13. Walter F. George	Chattahoochee	7,507	-	130.0	130.0	436,000	190.0	190.0	75	0	Pondage(c)	727	46.0	163.0	192.0
14. Berkley	Cumberland	17,639	-	130.0	130.0	600.000	375.0	359.0(c)	46	1,273(c)	202(c)	693	62.0	325.0	376.0
Total Southeastern			1271.0	536.0	1909.0	5,134,400				7,419	8,670	9,536			
OTHER															
1. St.Marys,Mich.	St. Marys	80,900	18.4	-	18.4	136,500	603.6	603.6	23	0	LAKE	SUPERIOR		591.0	604.0
GRAND TOTALS			6576.4	3904.0	14551.4	53,359,721				26,754	77,260	42,685			

(a) Gross Head - Difference between top of usable pool elevation and normal tailwater level.
(b) Includes power data from reregulating dams. Other data for Detroit and Lookout Point only.
(c) Flood Control provided by pre-drafting usable storage to provide necessary space.



Panorama of the Dalles Dam constructed by the U.S. Army Corps of Engineers on the Columbia River, 88 miles east of Portland, Oregon. The snow-capped peak of Mount Hood looms up in the background. This giant multi-purpose project was dedicated by Vice-President Richard M. Nixon.

Operation of the main-stem projects follows an operating plan which is based on the annual projection of needs as compared to the prospective water-supply. Minimum stream sanitation and water-supply requirements govern minimum releases on the lower river during the winter. Releases are correlated to that needed to meet firm power loads. Ice conditions during formation and breakup cause temporary adjustments in the operation schedule to meet emergency water-supply requirements at localities downstream.

Planning for Power

In all of these developments, the objective has been to obtain the greatest public benefit through careful planning and consideration of all of the uses which the development of a river basin may serve. The necessity of this broad approach is becoming more apparent all the time as good dam sites become scarce, and as we come to realize that our water resources are not unlimited. It is also essential that the multiple use concept be kept in mind because of the economy of combining several purposes in a single development. Whenever a project is studied for development under flood control or rivers and harbors legislation, full consideration is given to any potential power values that may be obtained. If there are such values, if there is a market for the output at a price that will recover costs, and if the power benefits exceed the increment of cost necessary to include them as a part of the project, the installation of generating facilities is recommended to the Congress. Where power development is not economical initially, or present demand is limited, minimum essential provisions for later installation of power facilities are included initially to make certain that future power is not precluded when found needed. Where water uses are complementary, or common space can be utilized at the same time or at specified times, the combination of uses increases the benefits while reducing the cost of each use. When water uses compete more extensive studies are necessary to determine the preferred use or dvelopment.

Research

Concurrently with, and closely related to, the planning activities of the Corps, is the research program under which we seek to find ways of doing the same job cheaper and better. Problems relating to the design, construction, operation, and maintenance of necessary structures for, and associated with, power development were occurring frequently during the initiation of multiple use construction by the Corps of Engineers. The problems were nation-wide and several localities had similar problems. In order to avoid duplication of effort in arriving at solutions, a continuing research program was initiated in 1947 to seek out answers to unresolved or incompletely solved problems. The program has resulted in many improvements in design and considerable economies in project costs. Discharge capacities of spillways have been increased by improvements in crest and pier shapes, resulting in reduction of the number of gated openings. Conduit and penstock entrance shapes have been improved to avoid cavitation dange and side gates have been developed that are suitable for use under high heads. Improvements in concrete technology include the use of low cement factor, large aggregate concrete made possible by controlled air entrainment, and the selection and control of optimum aggregate gradings. Other studies have led to the design of relief well systems for underseepage control at earth dams, principles of slope protection, use of sanded grouts for sealing rock foundations, and the development of the bore hole camera to aid in foundation explorations. Investigations of paint systems and cathodic protection for submerged metals have reduced annual maintenance costs for hydraulic structures. Among recent investigations are the studies which proved the feasibility of replacing up to one-fourth of the cement in mass concrete with relatively low cost fly ash or other pozzolans, and the utilization of electronic computers for intricate flood routings, reservoir operations, and power plant design problems. Observations of prototype structures and use of full-scale testing facilities are providing information not hitherto available from model tests. As new engineering problems arise, new research studies to provide solutions are initiated, provided the solution can be reasonably expected to result in a better structure at a lower cost.

The Future

Possible alternative sources of cheap power in the near future should not lessen the need for developing

economical hydroelectric power. The trend to larger turbine unit size has offset to some degree the rising costs of materials and labor. This trend reduces the cost per unit of hydro power capacity relative to the cost of an alternative source of power. A feature that is receiving more consideration lately is a pumped-storage type of development. This is especially advantageous where the peak demand for power is of short duration and the main power supply is by steam plants of fairly recent design, consisting of new large turbine unit sizes with high efficiencies. Taking these large steam units off load during off-peak periods is not economical and presents operating problems. Some utilities have found that utilizing the steam power off-peak for pumping water from an afterbay to the forebay of a hydro project for later hydro on-peak use is an economical way to increase the system supply to meet the load growth. This operation has been compared to a storage battery which would convert off-peak power to peak power.

We foresee a marked increase in the use of the pumped storage principle, and have already considered its possibilities in several instances. Also, the ever increasing demand for more power is improving the hydroelectric plant's position as a source of intermittent peak load power. We will be able to use available hydro energy to support greater peaking capabilities, which will make many projects economically attractive which are not justified under today's conditions. Thus, while many of our better sites for power have already been utilized, it is expected that hydro power will continue to be an important element of water resource development in the United States for many years to come.

(Continued from page 32)

REGIONAL DEVELOPMENT

cane plantation and a mill and refinery having a capacity of 30,000 tons of refined sugar per year. At the present time, the irrigation system is almost complete, the mill and refinery are under construction, and first full-scale production is scheduled for 1961.

These, then, are the first steps in a new regional development program patterned along the lines established in the Tennessee and Damodar Valley, and destined to join them as examples of the worth of careful planning for the combined use of all the resources of an area. There is no reason why these same principles, properly applied, cannot be adapted to the improvement in the lives of the people of many regions. India has experienced this with great success in the Damodar Valley and the ideas and techniques learned there can well be devoted to other regions. Assam comes to mind as a natural geographical unit with large potential. The world has a new and proven tool for raising the standard of living of its people. It should be put to maximum use in these days when there exists such a great imbalance between the highly developed nations and the vast masses of the world's population who must eke out a bare subsistence. The correction of this imbalance is one of the major problems of the day and true regional development can be a big factor in this correction.

(Continued from page 35)

ARE RIVER VALLEY PROJECTS WORTH THEIR LARGE INVESTMENTS ?

rites and the theoretical economists will have to find a rational conceptual framework in terms of which it is possible to describe the cumulative effects which are aimed at and which can be expected to accrue over their life span.

Thirdly, in the present context of the country's food situation, the choice lies between starvation on a mass scale and a bold policy in the development of the proved existing water resources of the country. Investments in other fields, howsoever vital for the overall economic, social and political development of the country can have only a secondary place compared to investments in river basin development. In order to sustain life people need water and food first.

Hassan Zaky
President
Sadd-el-Aali Executive Organisation

The Aswan High Dam Project

THE HISTORY OF THE DEVELOPMENT OF WATER SUPply for the production of food and fibre dates back to very early times. Egypt claims to have had the world's oldest rockfill dam 355 ft. long and 40 ft. high, built 5000 years ago to store water for drinking and irrigation. Again, in the days of Amenemhet II of the twelfth dynasty an outstanding project was carried out in Egypt for the exploitation of lake Moeris in Upper Egypt as a reservoir for storing up flood waters. The project was classified amongst the engineering marvels of the world.

While it would be an interesting study to fathom deeper into the ancient history of the art and practice of irrigation in Egypt, it was only towards the middle of the 19th century that construction of large scale irrigation works became technically feasible when the Delta Barrage was constructed across the Nile to command 3.5 million acres in Lower Egypt. The group of Dyrout Barrages was also built in 1878 to distribute waters on 1.5 million acres in Upper Egypt.

By the turn of the century many remarkable hydraulic structures were constructed on the Nile in Egypt. The original Aswan Dam completed in 1902 and since twice hightened, was designed to impound part of the annual flood for use in irrigation during the following dry season. Several big barrages were also constructed on the Nile downstream of the Aswan Dam to raise the water level sufficiently to feed the main irrigation canals. Recently the Aswan Dam has been put to a new use, that of producing hydro-electric power.

It should not be altogether surprising that Egypt is at present proceeding with the construction of one of the largest hydraulic structures in the world: THE SADD-EL-AALI (Aswan High Dam). It is a comprehensive plan for the utilisation of the water resources of the Nile for the expansion in cultivation, production of cheap hydro-electric power, protection against high floods, improvement of navigation and drainage conditions as well as for the development of fish culture and recreational facilities.

Hydrology

The longest and most remarkable river in the world is the River Nile. The length of its course from its remote source to the Mediterranean is about 4160 miles.

Since a very early period, the river has been conveying tremendous fortune to Egypt whose cultivation depends almost entirely on irrigation, but the problem of harnessing its water for the better security and prosperity of the people has always engaged their serious attention. Beside the constant threat of flood, there were years when the river flow was so reduced that it was not possible to provide sufficient water for the survival of crops.

The problem is mainly that of regulating the flow of the river Nile so as to avoid the extreme fluctuation of drought and flood and of obtaining the maximum benefits inherent in its potential resources. It is not only a technical problem but also a problem of realising the more fascinating task of bettering the standard of living of the fast multiplying Egyptian people and of helping to raise Egypt to the level of the great prosperous nations of the world.

During the last one hundred years much has been done to conserve the waters for irrigation purposes but up to the present time a large amount of each annual flood still flows to waste into the sea. The amount passing to the sea is, however, very variable being zero in the lowest year and almost 80 million acre-ft. in the highest.

For the present cultivated area in both Egypt and Sudan about 41 million acre-ft of irrigation water are required whereas the annual supply of the river may be so short as to threaten the country with starvation as happened in the year 1913-1914 when the supply throughout the whole year did not exceed 33 million acre-ft or, may be so high as to expose the country to destructive innundations as was in the year 1878-1879 when the supply reached 120 million acre-ft.

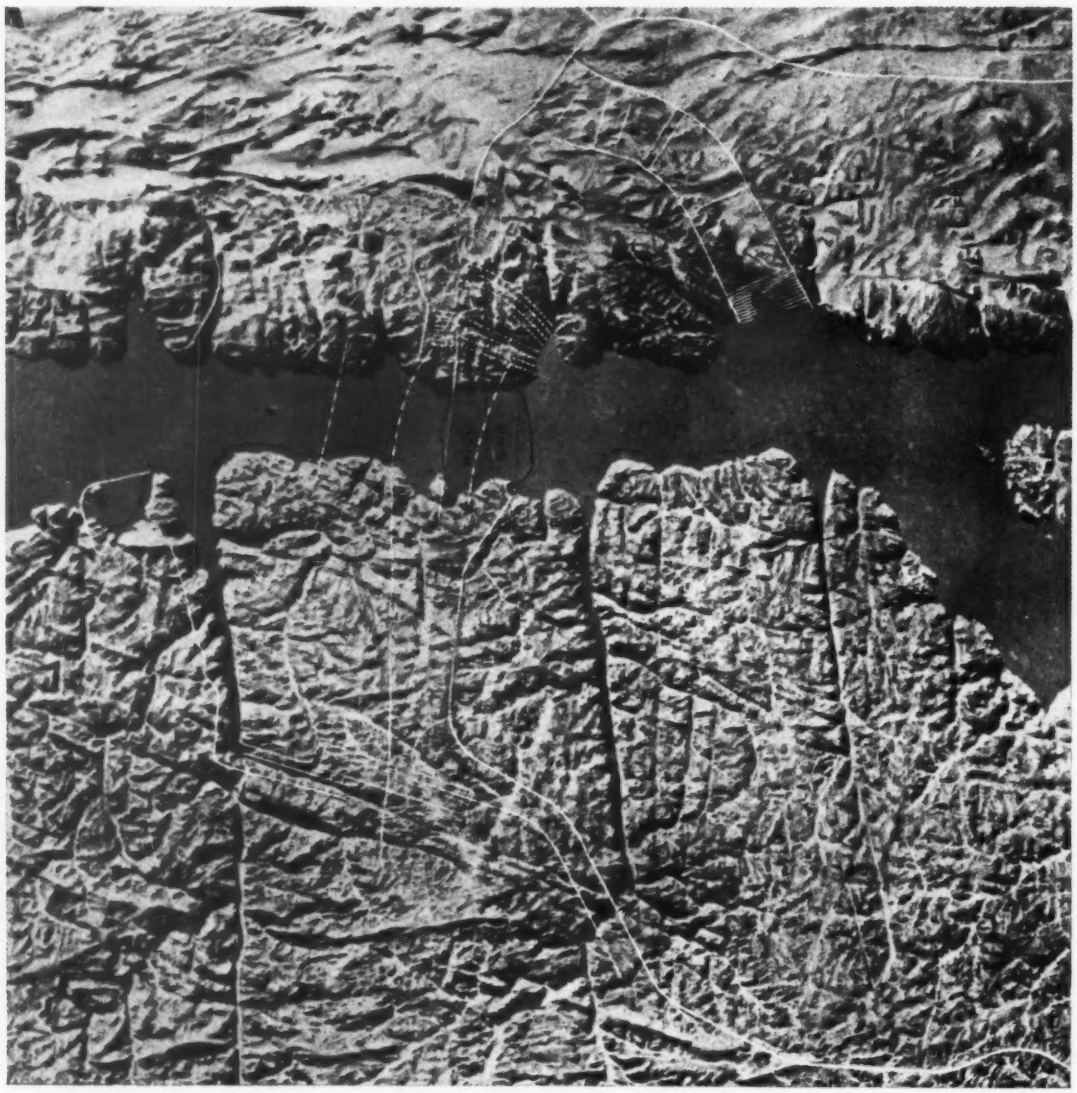
Again, while the present requirements for irrigation during the critical period of the year, from February to July, are estimated at some 17.5 million acre-ft. including annual storage water in both Gebel Awlia and Aswan Reservoirs which amounts to 6 million acre-ft. The natural supply of the river during the same period in 1914 was only 5.5 million acre-ft.

whereas in 1879 it was 30 million acre-ft.

These are two contrasting cases which explain the extent of the importance of these variations in relation to necessary requirements and make an urgent solution of this problem, an imperative necessity. However, the utility of the annual storage reservoirs is restricted to the detention of part of the comparatively clear water at a certain stage of the falling river to use it in the same year when the river is at its lowest. In some low years such reservoirs cannot be filled with the result that the present irrigation requirements cannot be guaranteed and any further development on annual storage runs the risk of disaster. In fact no further development is possible until some definite minimum quantity of water can be made available each year with a reasonable guarantee of certainty.

It is therefore obvious that the only way for complete solution of the problem is the use of the over-year storage which ensures the storage of all water surplus in excess of requirements in high floods to be drawn upon in years of low floods. For this, a large reservoir capacity is necessary since we have to add to our overyear storage a large capacity to contain deposited silt and a further capacity for flood protection.

Henceforth, came the idea that the development of



The selected site of the Sadd-el-Aali.

the River Nile for the major purposes of irrigation, power production and flood protection, would best be served by the construction of a high dam on the Main Nile at Aswan where we can deal with the whole volume of the river and store all surplus water.

Investigations

Reconnaisance survey including geologic, topographic and hydrographic investigations were carried out over a reach of 31 miles upstream of the existing Aswan Dam. In the light of the different investigations it was possible to find out that a storage dam with the required height could be constructed at two potential sites: a site located at 4.5 miles upstream of the Aswan Dam and another known as Kalabsha Site located about 26 miles upstream from the first site.

At the site of Kalabsha the stream channel is much narrower but it has many disadvantages. The terrain on both sides of the valley is so low that the crest of the dam would have a length of about 12 miles. Within the river channel the depth of water exceeds the corresponding depth at the first site by 50 to 65 ft. and at the same time the velocity of the water is much greater which means a more difficult condition for the construction of the cofferdam. Furthermore the construction of the dam at the Kalabsha site would reduce the capacity of the reservoir by 10 million acre ft. which are urgently needed for flood protection.

It was therefore decided that the High Dam should be built at 4.5 miles from the existing Aswan Dam.

As a result of other engineering studies which were carried out to furnish adequate informations concerning the practicability, efficacy and economy of the different method proposed for the construction of the dam, it was possible to arrive to the successful conclusion that the construction of a very safe high dam at the proposed site is feasible.

The optimum height of the dam was determined by cost benefit analysis and unavoidable annual evaporation losses.

Reservoir (Lake Nasser)

Water behind the dam will form the world's largest man-made lake. Its capacity will guarantee for Egypt and the Sudan enough water to meet their annual agricultural demands and at the same time permit a considerable expansion of the agricultural lands in both countries. The gross storage capacity of the new reservoir will exceed 104 million acre-ft. It will be divided into three parts:

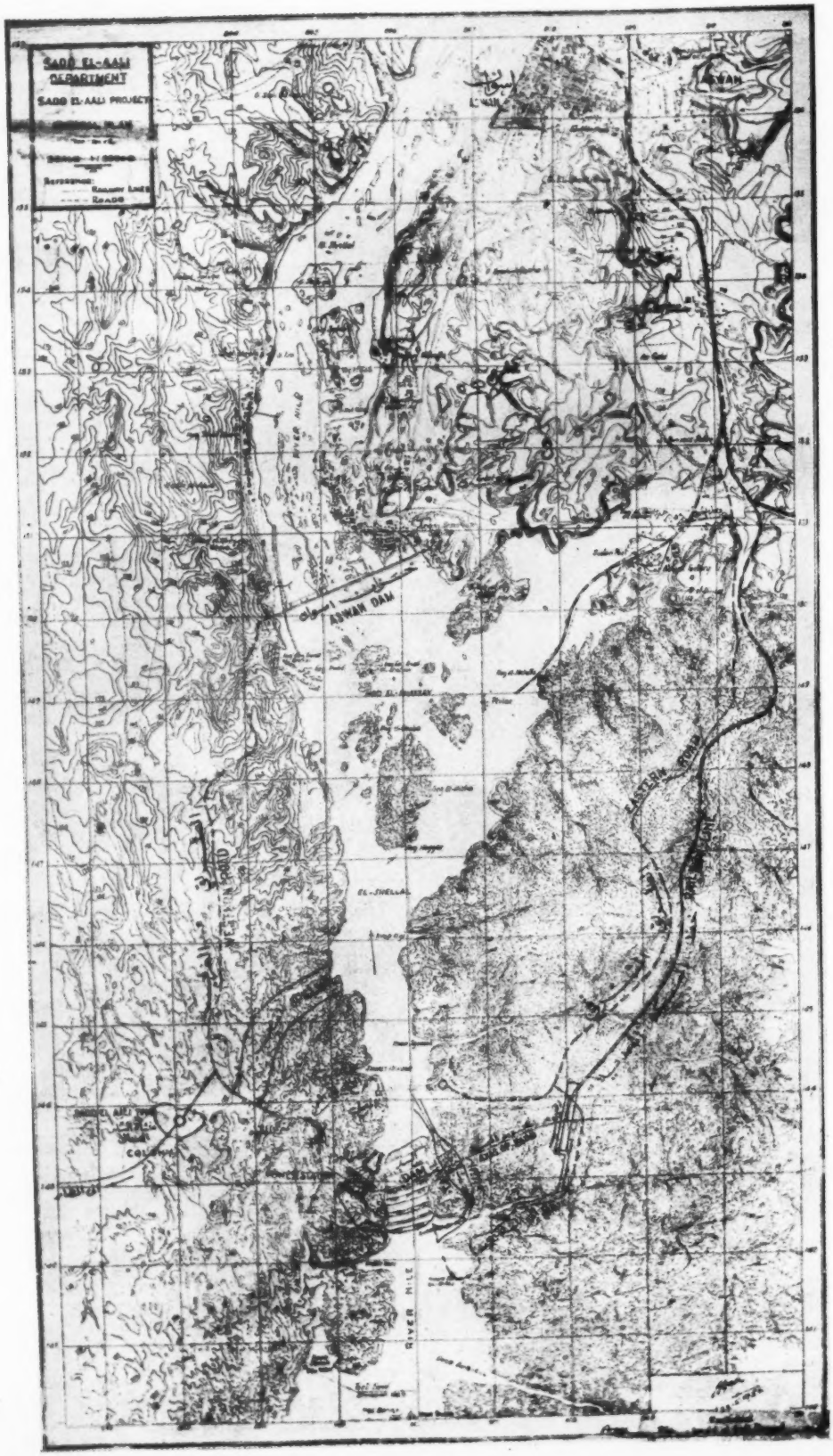
1. *Dead Storage :*

   of about 24 million acre-ft. to allow for silt accumulation. It is estimated that such capacity will be sufficient for the accumulation of the suspended matters in flood waters for a period of about 500 years before the live storage of the reservoir will be affected. The contents of this part corresponds to a level of 147 meters which is considered as the minimum level required to operate the power station at reasonable efficiency.

2. *Live Storage :*

   of about 56 million acre-ft. corresponding to the capacity between levels 147 & 175 meters. According to calculations based on current theories of overyear-storage, this capacity is sufficient to provide a constant annual draft of 67.2 million acre ft. As the average annual evaporation and seepage losses from the lake are estimated at 8 million acre-ft, the net annual draft from the Sadd-el-Aali will be 59.2 million acre-ft.

The Kalabsha Site.


SADD EL-AALI
DEPARTMENT
SADD EL-AALI PROJECT
ASWAN
ASWAN DAM
EASTERN POWER
RIVER NILE

Site Plan.

According to a recent agreement made between the United Arab Republic and the Sudan regarding the storage and the use of the reservoir, the share of Egypt will be 44.00 m. acre-ft. of water per year (55.5 milliard m^3) and the Sudan 14.8 million acre-ft. (18.5 milliard m^3). At present these shares are 38.4 and 3.2 million million acre ft. respectively.

3. Flood Control Storage :

of about 24 million acre-ft. corresponding to a full storage level of 182 meters. At the end of July, before the arrival of the flood waters, the reservoir level must not exceed 175 m. in order to have a sufficient capacity for receiving any dangerous flood. It is however, estimated that the allotted capacity for flood control will guarantee a full protection of the country against high floods without discharging big amounts of water downstream of the dam thus avoiding any potential degradation that might occur in the river channel.

The lake will extend 220 miles into Egyptian territory and approximately 95 miles into the Sudan. In places the lake will have a width up to 16 miles but it will be considerably narrower to the south.

According to a recent agreement, compensation will be paid to the Sudanese Government for the region which will be affected by the lake. As for the ancient temples within the new reservoir, they will be safeguarded through an International Assistance.

Dam Site

The selected site is ideal for a dam and looks as if it was made to order for the construction of a high dam. It has the advantage that both its banks rise steeply from the river bed so that a dam of only moderate length would be required and has a very wide valley on the upstream affording an excellent storage capacity.

Drilling of several vertical and inclined boreholes in the eastern and western river banks where the diversion channel and the power caverns will be located have shown sound rock of fine grain granite.

However, it has been believed that the river bed at the site of the dam consists of rock, but when the subsoil exploration was carried out, borings went very deep into numerous sedimentary deposits before striking sound rock. At the centre of the river channel, borings went 650 ft. below the bed of the river before striking sound granite. From some boreholes undisturbed samples of the underlying material were extracted by the freezing method and tested to determine the load carrying ability and percolation factor. The sediments forming the overburden consists mainly of well rounded quartz sand and quartz gravel frequently containing some large sound granite boulders. This especially applied to the upper sand stratum down to a depth of about 230 ft. below the bed level.

The lower stratum of the overburden consists not only of loose quartz sand and gravel but there also exist silt, clay lenses and petrified sand layers. The frequency and thickness of these layers increase from top to bottom where the silt is consolidated in a form of clay-schist layers or fine grained sand stone.

Near the dam a town site was selected where confortable living quarters are provided. The new town is located on the west bank of the river about one mile from the dam site at an elevation of 660 ft. above sea-level or 300 ft. above the river and is connected to the existing Aswan Dam by a hard surfaced highway. On the east bank another highway to the site was constructed. An access rail road 7 miles long was built from the nearest existing railway to deliver the quantities of materials that will be used in the construction of the dam. Work is now progressing to provide the construction site with working facilities and power on a high transmission line.

Design

Many difficulties were at first associated with the design of the dam. It has to be constructed on a pervious foundation in the lake of the existing Aswan Dam where the depth of water exceeds 130 ft. Again, the quantity of water which will pass at the dam site during its construction may assume in flood seasons volumes up to 390,000 c.f.s.

The engineers have had to face these intricate technical problems and it was really a challenge to their ingenuity to find solutions for these difficulties, the kind of which they have never encountered before.

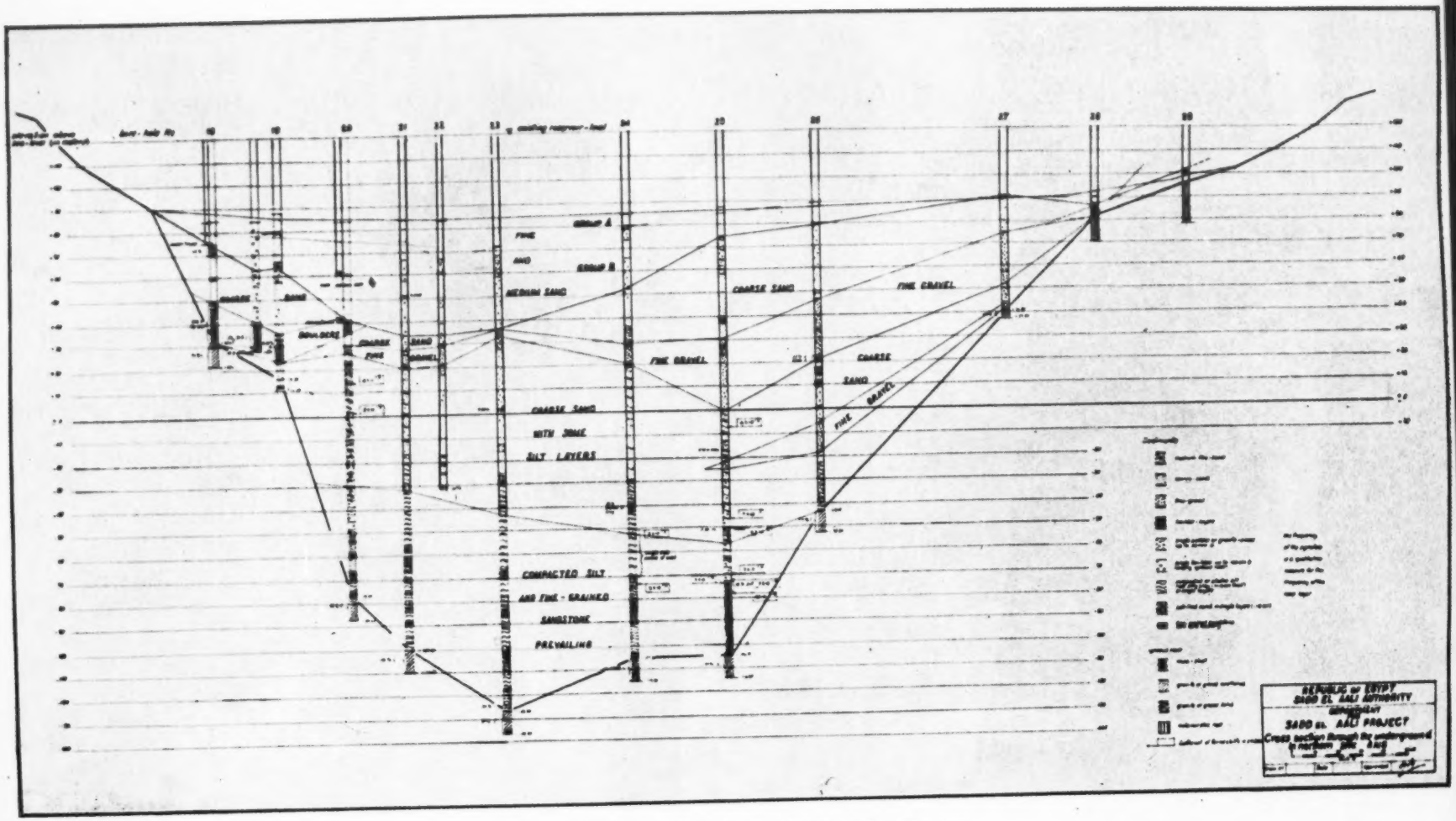
The natural features of the site offered insurmountable difficulties in regard to the construction of a concrete dam. On the other hand, these features, as well as other conditions concerning the availability of suitable construction materials in the vicinity of the dam site, were practically favourable for the realisation of a rockfill dam.

In designing the dam, its height was fixed within fairly close limits by the storage requirements. The top of the dam would necessarily be 360 ft. above the river bed. This height while exceptional for a rockfill dam, did not preclude consideration of the type.

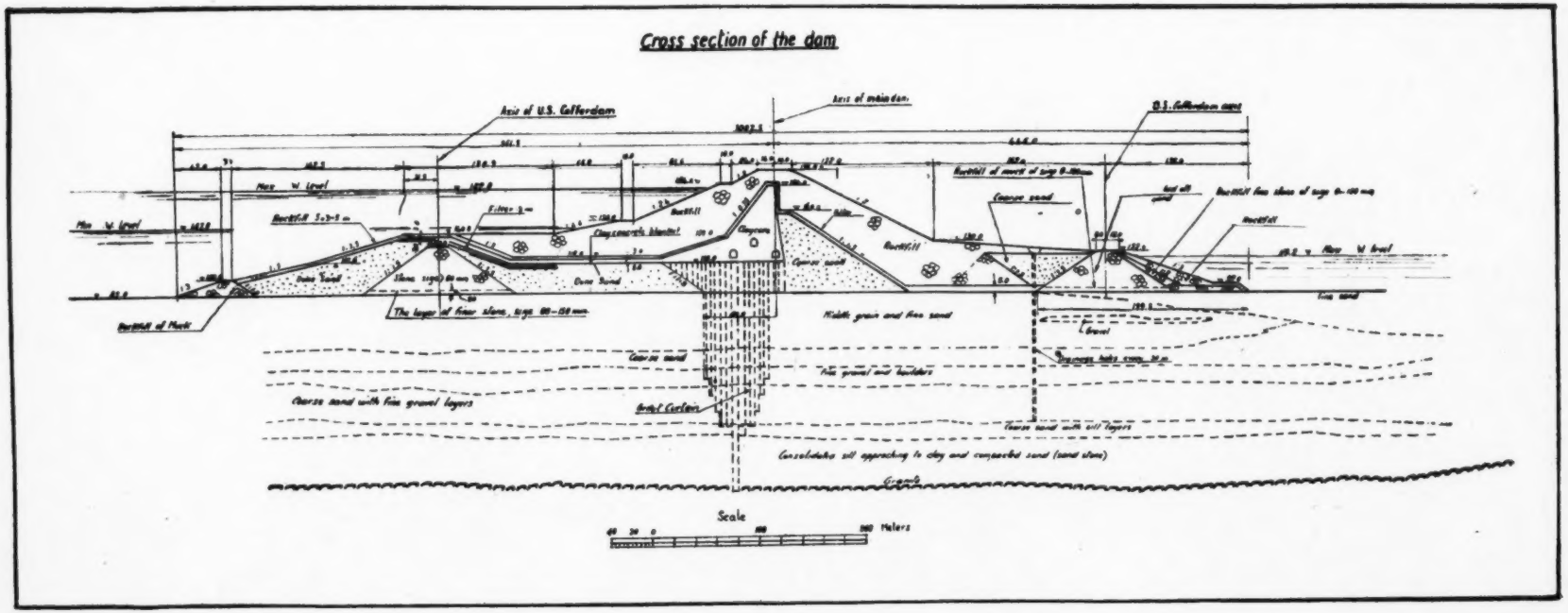
The length of the dam at the crest level will approximately be 2.2 miles of which 0.35 mile will be situated in the river channel. The width of the dam at its base level will be 3300 ft. and at crest level 100 ft.

The whole extent of the main dam foundation will be covered with a layer of compacted dune sand about 82 ft. deep. The rockfill above this layer will be equipped with a clay core roughly triangular in section with a base width of about 300 ft.

The dam will be protected against piping by two lines of defence: a horizontal impervious blanket in the upstream part of the dam, and a vertical grout



Cross-section through the underground at the axis of the dam.



Cross-section of the dam.

curtain descending in the overburden to bed-rock. The principal function of the grout curtain consists in plugging the voids in the layers and lenses of the open work gravel and coarse sand within the space located beneath the core of the dam. The upstream impervious blanket lengthens the percolation path and reduces seepage, while the pervious downstream part of the dam acts as an inverted filter to dissipate water pressure which would normally be built up in a foundation composed of material of varying permeability.

Three inspection galleries will be built into the clay core above the grout curtain which will be used for inspection, measurements and maintenance of the grout curtain throughout the life of the dam.

The exploration made for the materials of construction in the vicinity of the dam site showed that there are enough quantities of all the principal materials required for the dam and its central core.

Dune sand is available in unlimited quantities on the west slope of the Nile Valley near the site. Fully adequate coarse grained filter material could be obtained by dredging from the river bed and/or by a process of crushing and screening from the rock excavation. The rock material obtained from the diversion channel as well as from the power tunnels and open cuts will be used in constructing the rockfill part of the dam. Additional quantities of rockfill could be obtained from quarries within a moderate distance from the dam site. The impervious materials for the central core of the dam and the upstream foundation blanket, are a selected Nile silt. Two deposists of alluvial Nile silt have been investigated: one of these is located at Bahrif Island which lies at about 10 miles north of the existing Aswan Dam, and the other close to the downstream side of this dam. The clay required for the grouting operations could be obtained from the clay quarries in the Nubian sandstones near Aswan. The available quantities are far in excess of what will be needed.

All materials of construction have been subjected to laboratory tests and yielded satisfactory results. The coefficient of permeability of the Nile silt ranges between 1.2×10^{-9} and 8×10^{-8} cm/sec. its maximum dry density ranges between 1.47 and 1.69 t/m^3 and the optimum moist content ranges between 20 and 26%. Thus it has been proved that it is suitable as an impervious core material.

In order to furnish adequate information concerning the proposed grout curtain, two field tests were performed. The object of these tests was to ascertain whether or not it would be possible to impermeabilise the alluvials of the river bed by injection.

One of the field tests was performed near the left bank where fine sand predominates and the other near the right bank where the coarse sand predominates. In the coarse sand it was possible to reduce the coefficient of permeability from 2.5×10^{-2} to 2.3×10^{-4} cm/sec. whereas in the fine sand the reduction was only from 6.1×10^{-3} to 3.6×10^{-4} cm/sec.

These favourable results which were achieved at the two test blocks confirm that the grout curtain provided for in the project can definitely be accomplished.

Diversion Works

The general plan for the diversion works is to construct two cofferdams on the river bed upstream and downstream of the main dam so that the foundations of the main dam could be placed in still water. As soon as the river channel will be blocked by the construction of the upstream cofferdam, the flow of the Nile will be diverted through a diversion canal excavated in the east bank with control gates for keeping the flow of the river under control. Both cofferdams will remain an integral part of the high dam which will support on it. Consequently, there is no point in trying to build them to as economic value as possible.

In itself the upstream cofferdam will be a storage dam with a height of 160 ft. and approximately 1800 ft. long formed in a depth of 50 to 120 ft. of water. It will consist of rockfill with pores plugged up with sands. On the upstream side, the rockfill supports a wedge shaped body of dune sands serving the purpose of reducing the seepage through the cofferdam to a tolerable value. Naturally, the river will help to make the cofferdam water-tight by depositing silt against its upstream side.

During construction, it will be necessary to control the flood by the existing Aswan Dam in order to protect the crest of the upstream cofferdam at its different stages of construction. In fact the existence of the Aswan Dam facilitates the construction of the cofferdam to a great extent. If it had been necessary to build the same cofferdam at the same site prior to the construction of the existing dam, the difficulties involved would have been far more serious. By the help of the Aswan Dam all flood waters in excess of irrigation requirements could be kept in the reservoir until the depth of water over the crest of the cofferdam reaches some 60 ft. thus reducing the velocity of the flow. It is only when the water level reaches this value that the gates of Aswan Dam may be opened to pass the flood.

After the crest of the upstream cofferdam has been raised to a level of 135 meters and the diversion channel is completed, the reservoir formed by the cofferdam can be utilized for the expansion in cultivation. Therefore, the completion of the cofferdam, which is expected to take place towards the end of the year 1964, can be considered the first stage in the realisation of the irrigation project.

The downstream cofferdam consists of rockfill resting on an inverted filter, with an apron of large boulders on its downstream side for protection against scour by the water leaving the diversion canal.

General Plan of the Project.

Through the granite forming the east bank of the river an open diversion canal will be cut. In the part of the canal where it crosses the main dam, the virgin plug will be left in which 6 control tunnels with service gates will be provided. Thus the diversion channel will consist of 3 parts: upstream canal 2800 ft. long, control tunnel spillway 750 ft. long and downstream canal 1180 ft. long. The total channel length will be 4730 ft. The canal will have a bed width of about 200 ft., its maximum depth will be about 260 ft. with side slopes of 5:1, and will be capable of passing a maximum flow of 390,000 c.f.s. It will be the biggest canal in the world.

Each control tunnel will have a finish section of 46 ft. wide by 44 ft. high, fully lined with concrete and equipped with two vertical iron gates 16×36 ft. designed to pass all irrigation requirements and flood waters during the period of construction of the dam with a maximum loss of head of about 40 ft.

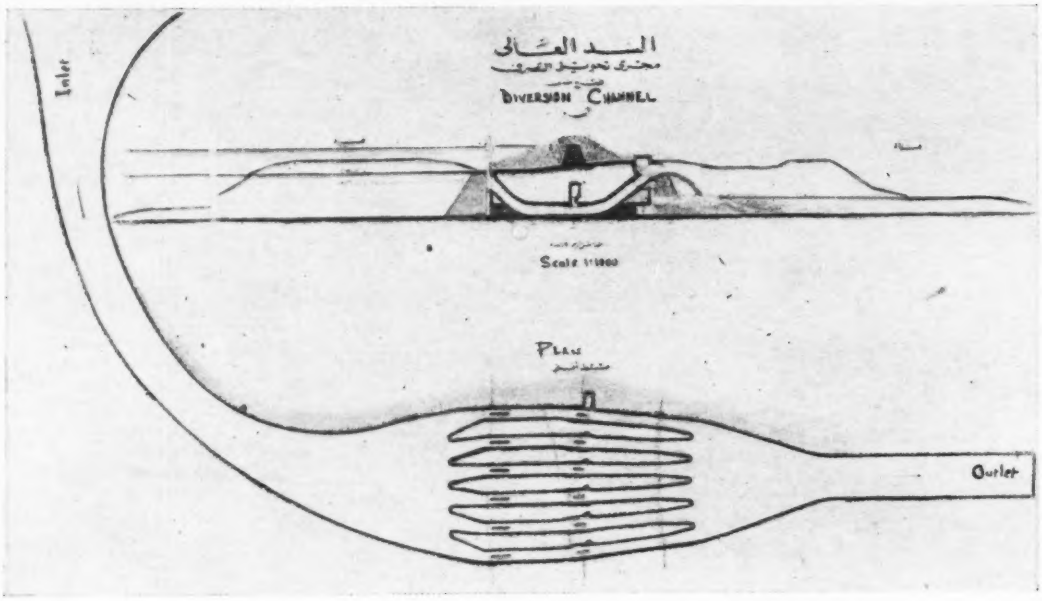
After completion of the main dam, the tunnels will be equipped at their downstream end with radial gates to control the passage of irrigation requirements under high heads and to pass unusual flows.

An emergency spillway on the west side of the dam with a sill level at 180 meters is designed to protect the major structures from the effect of exceptional or unprecedented flood flows. It will be capable of discharging about 8000 c.f.s. at a level of 182 meters.

Power Plant

At present, the main source of power in Egypt is petroleum. Of the total annual energy consumed, which amounts to 2000 million kWh, 99% is generated by thermal stations. However, the picture will soon be changed due to the completion of the hydro-electric power station at the existing Aswan Dam, which will run at full capacity early in 1961 to generate about 2000 million kWh annually. According to this new development, the per capita consumption of electric power in Egypt will rise from 80 to 160 kWh. The per capita consumption of electricity per head, in other industrially advanced countries like U.S.A. and England reached 4400 & 1270 respectively. This is an indication to the uphill task Egypt has to make up in the direction of electric power industry.

The construction of the Sadd-el-Aali will realise the production of an enormous amount of cheap hydroelectric power. At the west bank of the river, the surface topography and rock conditions lend themselves well to the construction of an underground hydro-electric power station. The water being conveyed to and from the power station by a head race and a tail race of open canals. The Power Plant is designed for an ultimate installation of 16 main geneting units of 150,000 kilowatts capacity each, making a total generating capacity of 2,400,000 kilowatts. It will be the biggest underground power plant ever constructed anywhere in the world.



Diversion Channel.

The water turbines will be of the Francis type, in steel spiral casings, and will have vertical axis. The governing principle in determining the size of these turbines has been to obtain as large units as is practicable and consistent with economy of manufacture. The net head on the turbines will vary from 240 to 160 ft. and the rated discharge through one unit at the maximum output will be about 8000 cubic feet per second.

Transformer galleries will be placed underground, immediately downstream of the power chambers. The main transmission cable will be led by shafts to the outdoor switching station overhead. The outdoor switching station will be located immediately above the transformer galleries. It will be built in terraces on the sloping ground and will have system of double bus bars to which the groups of transformers will be connected.

Transformation will be from 18 to 400 kV with provision for transmission at the latter voltage to Cairo, a distance of approximately 480 miles. In the ultimate stage there will be six 400 kV transmission lines equipped with twin conductors in each phase and also with series of capacitors for obtaining the necessary stability.

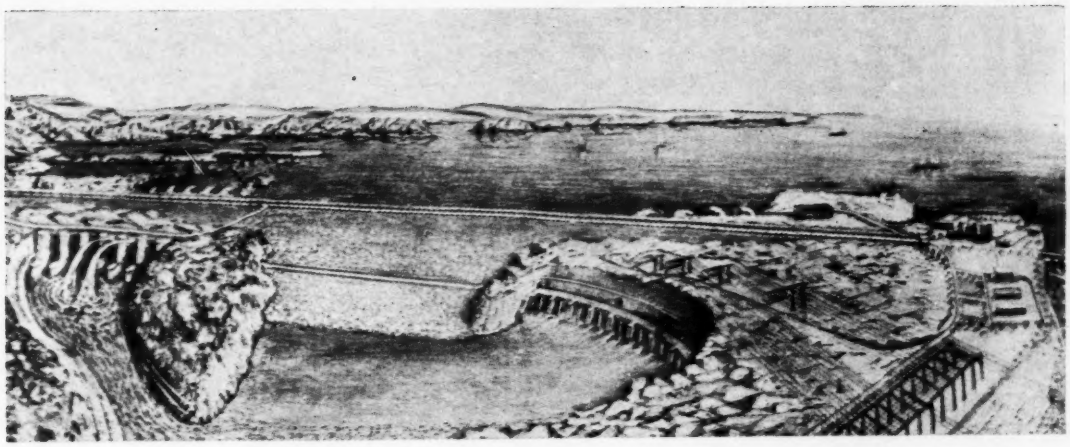
Investigations are in progress with the view of increasing the voltage to 500 kV. If technical problems connected with the transmission at this tension have been solved and if estimates of cost show economic advantages, the voltage will be increased to 500 kV. The higher voltage will reduce the number of the main transmission lines, and may also affect the number of substations between Aswan and Cairo.

It is estimated that at the ultimate stage when the 16 machine units are installed, the total annual energy generated from the Sadd-el-Aali hydroelectric power station will amount to 10,000 million kWh, with a cost production of 0.5 millieme per unit energy at Aswan and 2 milliemes at Cairo. This Hydro-power station will eventually operate in conjunction with that at the existing Aswan Dam and the full capacity of the two stations together is stated to be about some 12,000 million kWh.

In fact the construction of the Sadd-el-Aali is considered a major step towards the full utilisation of the natural water potentialities of the River Nile in the production of power. The total water power potential of the river in Egyptian territory is estimated at about 17000 million kWH. For the exploitation of the full power potential, preliminary studies are progressing with a view to constructing additional power plants on the river at the following sections.

- — At the existing Aswan Dam for the generation of an extra 1000 million kWh annually.
- — At the three existing barrages on the Nile in the distance between Aswan and Cairo.
- — At six new barrages which would be constructed within the same reach of the Nile to fully utilise the total drop of water from Aswan to Cairo.

As the construction of the Sadd-el-Aali will guarantee a practically constant level in the river downstream of Aswan all the year round, a constant head of water could rather be kept on the existing as well



An artist's conception of the Sadd-el-Aali.

as new barrages and consequently a good amount of firm power estimated at some 4300 million kWh annually could be produced at these barrages.

Equipment & Materials of Construction

The total quantities of the various materials required for the construction including rockfill, sand, silt, etc., are estimated at about 50 million cubic yards.

The required quantities of iron works will amount to nearly 95 thousand tons including the gates of the diversion canal which will regulate the flow of the river and which will require special designs to meet the severe conditions under which they have to operate.

An enterprise of such magnitude will require the use of huge mechanical equipment of massive strength and reliability estimated at 25,000 tons. It will be of the most efficient and modern types of machinery to ensure safe and fast operation and to enable the economic handling of big quantities of materials which may reach 47000 cubic yards per day during certain peaks of construction. The operation of such equipment will, in turn, necessitate the provision of an immense electric power estimated at 20,000 kilowatts. This amount of electricity is available from the existing Aswan Dam hydroelectric power station.

The organisation of such work and the drawing up of the execution plans and programmes will not only call for an outstanding technical efficiency and experience but will also require a vast and ample knowledge of the flow of the river in order to facilitate the diversion of its waters through an artificial channel without encroaching on the water requirements of the existing cultivations by any means.

Estimate of Cost & Benefits

The total expenditure for the construction of the Sadd-el-Aali and auxiliary works are estimated as follows:

Cost of the Project & auxiliary works	*Million Pounds*
1. Cost of constructing the Sadd-el-Aali including cost of civil works for the power plant and indemnities for Nubia and Wadi Halfa.	125.0
2. Cost of 16 turbine units and a transmission line to Cairo with its branches.	90.0
3. Cost of irrigation & drainage projects necessary for the conversion of basins and the reclamation of one million feddans.	85.0
4. Cost of constructing roads and other public utilities in the reclaimed area.	19.5
Total of public investment.	319.5
5. Cost of preparing basin lands for perennial irrigation	7.0
6. Cost of reclaiming one million feddans.	70.0
7. Houses for the new reclaimed areas	21.0
Total of private investment.	98.0
Total cost of the project excluding interest of capital during the period of construction.	417.5

Benefits

The following is a summary of the special advantages from the dam to the U.A.R.

1. Expansion of cultivation in about 1.7 million feddans including the conversion of nearly 700,000 feddans in Upper Egypt under basin irrigation to the perennial irrigation system thus increasing the present irrigation area by about 30%
2. A guarantee of water requirements for the existing and the new areas under cultivation even

in the years of low supply thus increasing their yield.

3. Improvement of drainage conditions in all cultivable areas thus increasing their output and saving considerable costs of drainage schemes.

4. To guarantee the cultivation of 700,000 feddans of rice every year.

5. Complete protection against high floods thus saving considerable amounts now being spent by the Irrigation Department every year for the hightening and strengthening of the river embankments. This is in addition to eliminating damage caused to many cultivation as a result of the infiltration of water and saving the efforts of the Nile watchmen during flood periods and diverting their efforts to agricultural production.

6. Improving navigation conditions.

7. Improving the hydraulic conditions upstream the existing Aswan Dam almost doubling its firm power capacity.

8. To guarantee a head of water on the existing barrages on the Nile all the year round for the production of hydro-electric power with the practicability of constructing more barrages on the Nile so as to fully utilize the total drop of water from Aswan to Cairo in the production of hydro-electric power. Such new barrages will flatten the slope of water in the river thus eliminating any harmful degradation in the river bed due to the flow of clear water down stream of the high dam.

9. Producing hydro-electric power potential of about 10 milliards kWh per year i.e. about five-fold of the energy now being consumed by the Egyptian Region, which will help create new industries and flourish the existing ones.

10. A reduction in the annual consumption of mazout by about two million tons.

11. To improve the balance of Egypt's international payment as it will result in a considerable savings in annual imports besides affecting more export earnings.

12. To employ hundreds of thousands of labour in the reclamation of land and in the new industries.

Expressing these advantages in figures, it can be concluded that, as a result of this project, the United Arab Republic will realise an increase in the national as well as the Government revenues estimated in millions of Egyptian Pounds as follows:

A. *increase in national income :*	*Million Pounds*
1. Increase from expansion in cultivation in about one million feddans and conversion of basins in Upper Egypt to perennial irrigation.	63
2. Guarantee of water requirements for all the existing and the new reclaimed areas even in the years of low supply and improving their drainage conditions besides the guarantee of cultivating 700,000 feddans of rice every year.	56
3. Protection against high floods, prevention of seepage to lands alongside river embankments and protection of islands and river banks from inundation.	10
4. Improving navigation conditions due to a full control of flow downstream of the Dam.	5
5. Production of a hydro-electric power potential of about 10 milliards kWh per year and improving the economics of the Aswan Dam hydro-electric power station.	100
TOTAL	234

B. *Increase in Government income :*	
1. Increase of Government income from taxation on new cultivated areas & from extra taxation on existing areas due to the improvement of their output.	9
2. Increase of Government income as a result of improving navigation conditions and from saving expenditure on flood protection measures etc.	2.5
3. Increase of Government income from the proceeds of the Sadd-el-Aali power scheme.	10.5
TOTAL	22

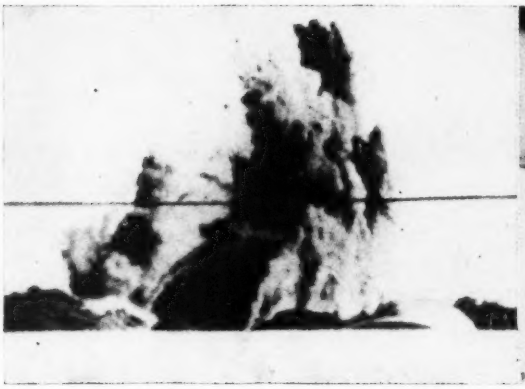
It is, therefore, revealed that the proportion of the annual proceeds of the project to its total cost is equal to 56% which means that the project will cover its whole cost in less than two years. This is in addition to the other amounts which the Government will earn due to land enhancement caused by reclamation works.

For the Sudan, the Sadd-el-Aali means the following benefits:

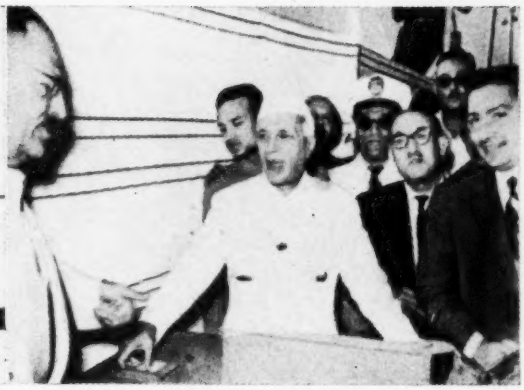
1. Agricultural expansion in about threefold the existing cultivated area.

2. To guarantee water requirements for the present and new cultivated areas.

3. To secure a large-scale development in cultivation of long-staple cotton.



The first blast marked the historic opening of work in the Sadd-el-Aali.



The Prime Minister of India, assisting in the execution of the project by pushing a button that exploded 10 tons of dynamite and shattered a rocky cliff on the east bank.

4. To increase the annual government and national incomes from agriculture by about 300%.
5. To benefit from the dams which the Sudan Government is now constructing and to use the energy of the water in generating hydro-electric power.
6. To guarantee a long life for the reservoirs of the Sudanese dams since they will be filled with more or less clear water.

Construction

On the morning of the 9th January, 1960, President Nasser strode forward and jabbed at a push-button near the dam site, with a flash and a roar 10 tons of dynamite exploded on the bank of the river marking the historic opening of the work in the project whose completion will necessitate 7 to 8 years of digging and building.

As a result of the first blast 20,000 tons of granite cliff at the site of the diversion canal disintegrated, moments later, through the drifting dust came craws of steel-grey bull-dozers and an army of workers rushing forward to begin cleaning away the mountain of debris.

Four months later, India's Prime Minister Pandit Nehru, during his visit to the site of the Sadd-el-Aali at Aswan, was invited to assist in the construction of this project. This he did by pulling a switch that set off another 10 tons of dynamite and shattered a rocky bluff's face on the east bank.

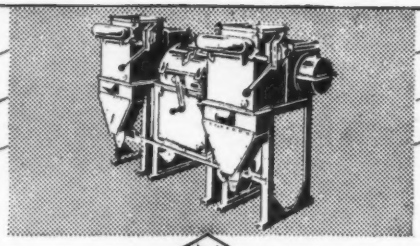
Work is now progressing round the clock according to schedule. The once empty desert round Aswan is now humming with activity. For the past six months technicians have been supervising the unloading of L.E. 2 million worth of heavy constructional equipment. The number of labour is at present about 2000 and may reach 6000 per day during the peaks of construction.

Conclusion

The Sadd-el-Aali is a productive and protective plan of the first order. It might not be the largest nor the highest dam ever built but it can justly be considered as the pioneer storage work in the whole world. The works must not be appraised only in terms of their magnitude but principally in terms of their benefits. In this respect, there is no other storage work in the world that realises so much benefits with the least expenses as the Sadd-el-Aali.

As already mentioned, the materials involved in the construction of the Sadd-el-Aali may exceed 50 million cubic yards. This big volume is about 16 times greater than the great pyramid of Cheops which was foremost amongst the engineering marvels of the world, and it is of interest to state here that while the great pyramid was built thousands of years ago to ensure life after death to the Pharaohs, yet the gigantic construction of the Sadd-el-Aali, more magnificent than the great Pyramid is now built to ensure higher standard of living for all the people of Egypt.

There is no doubt that the benefits of this colossal enterprise will have deep and far reaching consequences that will be felt not only by this generation but also by many future ones. Through these benefits and other indirect returns, the Sadd-el-Aali will amply demonstrate its economic and social value to a greater Egypt.



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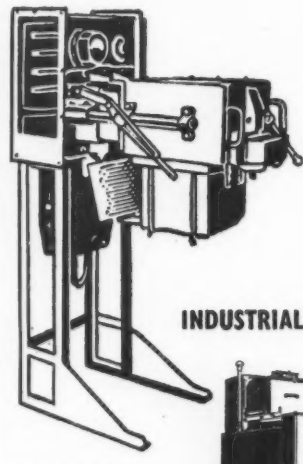

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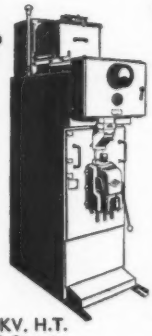

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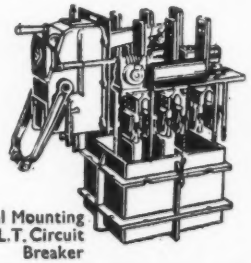

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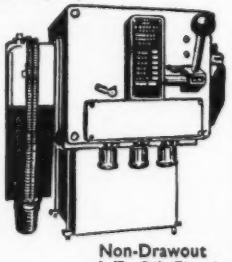

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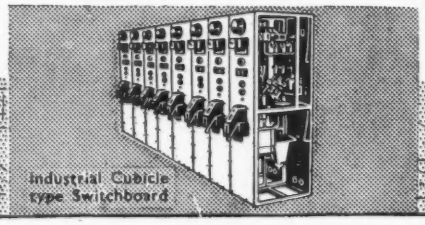

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M. Hayath
Chairman
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Power Development in India : Outlook for the Future

THE HISTORY OF POWER DEVELOPMENT IN INDIA dates back to early 1900. From the turn of the century up to the start of the Second World War, power development in this country was characterised by extremely small demands for power and almost imperceptible rate of growth of demand. These loads were mainly concentrated in a few urban areas, generally remote from hydro resources. Thermal generation was both sufficient and appropriate in most cases and hydro generation was resorted to only under specially favourable natural circumstances. The area of power supply was confined to urban centres and to the limited reach of the few pioneering hydro schemes. In the period during the Second World War and thereafter, striking increases were registered both in the magnitude of load demands and in their rapid growth due to the increased tempo of industrial and other developmental activities. In fact, the planned development of power began only after the ushering in of Independence, when steps were initiated for rapid and planned increase in the national income and living standards.

Power Development during the First Five Year Plan

By the end of 1947, the installed capacity of power generating plants in the country was about 1.36 million kW. At the beginning of the First Plan in 1951 this had increased to 2.3 million kW comprising 0.6 million kW in the public sector and 1.7 million kW in the private sector and self-generating industrial establishments. The target for the First Plan was fixed at 1.3 million kW of which 1.1 million kW was to be provided by the public sector and 0.2 million kW by the private sector. The total provision for expenditure on power projects included in the First Plan amounted to Rs. 260 crores including the proportionate costs on power for multi-purpose projects. In major river valley projects like Bhakra Nangal, Damodar Valley, Hirakud, Chambal, Koyna, Rihand, etc. where extensive civil works were involved, some delay was experienced during the initial stages in completing the investigations, in revising the scope of the projects and in setting up the necessary organization for their execution. In addition, as the country had to depend largely on imported machinery and equipment for power generation and transmission, delays occurred due to protracted deliveries from foreign manufacturers. Difficulties in the procurement of materials like steel and cement were also experienced to some extent. Despite these difficulties, the public sector accomplished installation of 0.8 million kW of generating plant and the private sector installed the full target of 0.2 million kW. No target was set for power plants in the industrial establishments. A number of them closed down their less efficient generating plants and changed over to bulk supply from public utilities' grid systems. However, there was a net increase of about 0.1 million kW in the power plant capacity of industrial establishments bringing the total generating capacity added during the First Plan to 1.1 million kW. The total installed generating capacity by the end of the First Plan thus increased to 3.4 million kW, comprising 1.4 million kW in State-owned power stations and 2 million kW in the private sector.

Power Development during the Second Five Year Plan

At the time the Second Plan was formulated, a target of 3.5 million kW was set for power development. The Second Plan covered tentatively 37 power generating schemes continuing from the First Plan aggregating to 2 million kW and 65 new power generating schemes including schemes in the private sector and self-generating industries aggregating to 3 million kW. The Plan target was anticipated to be realised through schemes continuing from the First Plan which was expected to yield 1.7 million kW and by new schemes contributing another 1.8 million kW. The Second Plan target also envisaged the construction of adequate transmission lines (35,000 miles of high voltage lines) and the necessary transformer stations and the electrification of about 10,000 additional towns and villages. A financial outlay of 427

crores had been provided for the schemes included in the Second Five Year Plan.

The power development programme of Second Plan has since undergone some changes from time to time due to various reasons. At the time of formulating of the Plan, most of the schemes were tentatively included, subject to their being found technically and economically feasible. Some schemes had to be modified as a result of such detailed technical studies and in some cases changes were necessitated to meet regional power needs. In some areas, the demands from the industries and other essential loads have grown so rapidly that it has been found necessary to provide additional capacity or to increase the scope of the projects already included. The most important factor which has significantly altered the scope and progress of the schemes in the Second Plan has been the shortage of foreign exchange required for import of plant and machinery from abroad. In spite of efforts made in securing foreign exchange in the form of loans from certain countries for supplementing our meagre resources, the shortage has been keenly felt and it has become clear that it will not be possible to complete some of the power projects in the Second Five Year Plan as originally programmed.

Accordingly, the planned targets were reapprised in April 1958 in the context of foreign exchange resources available and the power development schemes included in the Plan were divided into two broad categories, namely, (a) schemes included in the core of the Plan, i.e. those which were accorded highest priority, and (b) non-core schemes of lower or no priority. According to this classification, 18 power generating schemes included in the Plan envisaging installation of 1.13 million kW were listed under the latter category. This reappraisal of the Second Plan programme therefore resulted in a revision of the original planned target from 3.5 million kW to 3.0 million kW. Although every effort has been and is still being made to proceed with the entire programme to the extent possible, the foreign exchange difficulties and the consequential delay in proceeding with a few projects as a result of the delay in ordering of the plant and equipment are expected to result in a shortfall from even the revised target of 3 million kW. According to the present anticipations the actual realization of benefits within the Plan period from schemes continuing from the First Plan would be 1.3 million kW and another 1.1 million kW from new schemes giving a total of 2.4 million kW. In other words the installed generating capacity by the end of the Second Plan would be 5.8 million kW as against the original target of 6.9 million kW and the revised target of 6.4 million kW.

Programme for the Third Plan

The Third Five Year Plan envisages an outlay of Rs. 975 crores for power, of which Rs. 925 crores will be in the public sector and Rs. 50 crores in the private sector. The approximate break up of the outlay in the public sector is Rs. 580 crores for hydro and thermal generating schemes, Rs. 51 crores for atomic power and Rs. 24 crores for uranium mining and Rs. 270 crores for transmission, distribution and rural electrification. The target envisaged for the Third Plan is an addition of 6 million kW generating capacity comprising 2.4 million kW from schemes continuing from the Second Plan, and 3.6 million kW from new schemes. The above figures are only rough indications and detailed discussions with the various State Governments are presently going on with a view to determine the increase in generating capacity necessary in each State in relation to the load demands expected.

Power Resources

On the basis of a very conservative forecast, it has been estimated that the total installed generating capacity in India after 25 years from now would be of the order of 55 million kW. In this context the position regarding the power resources in our country is reviewed below:—

The hydro-electric resources of the country as assessed at present from the available topo sheets are estimated at over 40 million kW. This represents the potential for the sites which are capable of being developed economically on the basis of present day costs. As experience has shown, detailed investigations are likely to reveal not only a higher potential for the sites studied, but also additional sites of generation are likely to be discovered, thus increasing the available hydro-electric potential of the country considerably. Apart from this, on the borders of India, particularly in the Himalayas and in the Brahmaputra River, very large hydro-electric resources exist. With the technical developments in the field of high tension transmission practice, it may not be uneconomical to tap these resources and transmit the power over long distances. The present known hydro-electrical potential is, more or less, adequate to meet the load demands in all the States, except West Bengal, Bihar, Madras and Bombay, for sometime to come. In the case of the States of West Bengal and Bihar, even though hydro-electric potential is limited, the coal resources of the areas are very large. In particular, the extent of availability of poor quality coal as assessed at present, which is not useful for any purpose other than power generation, is understood to be very large. New fields are being discovered every year. Further, with the establishment of large washeries for providing coking coal for steel plants, huge quantities of middlings will be available which could be beneficially utilized for generation of power. The utilization of low grade coal as well as washery middlings is of special significance in the national economy for the steel industry. Washing of metallur-

gical coal is an essential operation for supplying good grade coal for the steel industry and in this process, large quantities of middlings are produced. Unless these are utilised on the spot, they would go to waste and coal for the steel industry would become very costly. Very large deposits of poor grade coal are also a national asset and should be put to good purpose. As it is not worth carrying them over long distances, the obvious methods of exploiting would be to locate large pit-head power stations and carry the power to long distances by means of extra high voltage lines. In addition to hydro and coal resources, efforts are being made to establish nuclear power stations and develop the fuel for them indigenously. A start is being made by putting up a 300 MW nuclear power station in the west coast of India and larger installations may follow during the next plan periods.

Recently, investigations are being carried out for locating oil and natural gas resources. Oil has been discovered in the Cambay region in Gujarat and natural gas will be available in the course of production of crude oil in the oilfields around Nahorkatiya in Assam. It has been decided to establish a gas-turbine power station with initial installed capacity of 50 MW at Nahorkatiya utilising natural gas.

Future Prospects

Research in the manufacture of thermal generating units has resulted in the continuous increase of the size of the units. Generating sets of 120 MW and over are now common in many parts of the world. Even larger units upto 650 MW (2-shaft unit) are under construction. Even though, in the past, we have installed in this country smaller size units to meet local needs, the time has come when we have to adopt large size units with higher pressures and temperatures to secure maximum economy in the field of power generation. Two 120 MW units have already been ordered for installation in the DVC system and more will follow in due course in several parts of the country.

Many of the rivers in the country have large variations in their flow during the year. Hence large storages will have to be constructed if the flow of the rivers is to be regulated for generating large amounts of firm power. Construction of such storages are costly. Further, in certain seasons like monsoon, large discharges are available in the rivers and these could be harnessed provided hydro stations are linked with thermal stations. Hence, for securing optimum exploitation of natural resources, integrated operation of hydro and thermal power stations is necessary.

The trend in the various States has been towards the interconnection of their important generating stations within the States, but there has been no significant expansion of regional grids across the State boundaries—except in the case of Damodar Valley Corporation area, Chambal area and Bhakra-Nangal area where more than one State is involved in the development of the multi-purpose schemes. With the growth of power systems in the individual States, necessity of inter-State transmission links is being increasingly realized. A start will be made in the Third Five Year Plan by constructing a few 220 kV transmission links between Andhra, Madras, Mysore and Kerala States to overcome power shortage and help economic co-ordinated operation of the grids. Also Gujarat and Maharashtra States will be served by a 220 kV inter-State link to utilize the nuclear power to be generated in Maharashtra (very near the border of Gujarat) and this link would also help co-ordinated operation of the grids of the two States. The inter-State link between Madhya Pradesh and Uttar Pradesh interconnecting Rihand hydel and Singrauli thermal stations in U.P. with Korba thermal station in Madhya Pradesh may materialise in the near future. The DVC, Bihar, West Bengal grids may be further reinforced and inter-connected with Hirakud-Talcher grid in Orissa. The necessary studies and collection of data for formulation of schemes for inter-State transmission links and operation of Zonal grids are in hand.

Electro-metallurgical and electro-chemical industries like Aluminium, Fertilisers, etc., require large blocks of power and it is obvious that such industries should be located as near to the source of cheapest power as practicable consistent with other factors such as availability of raw materials, labour, etc.

The country has to plan for a vast power development programme keeping in view the large industrial developments necessary for raising our living standards. Large hydro-electric projects and large size thermal generation schemes will have to be undertaken if the demand for power for the rapid industrial development is to be met in an adequate measure and at economical rates. To achieve this purpose, we have to get away from the parochial approach with regard to the establishment of power generating stations and location of heavy industries. The problems will have to be tackled on a national basis rather than on a State basis.

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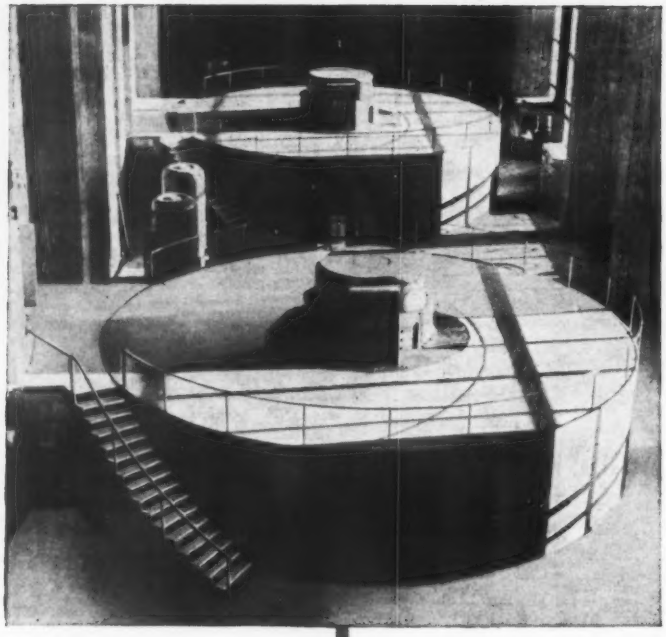

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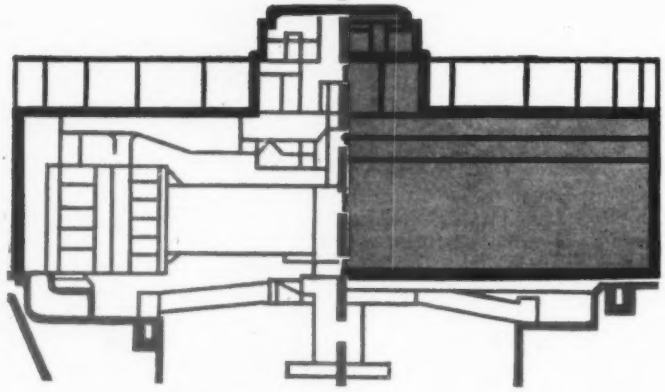

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Charles Jaeger
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Integration of Hydro Power in Large Expanding Electric Systems

Estimate of required capacity and discussion of price patterns

1. The electric industry all over the world is developing rapidly. It is expanding at a rate of about 4 to 8 percent a year, depending on the countries and its structure is being slowly altered. Base load energy is generated in ever more powerful steam stations and in large hydro power developments—often located at great distances from the centres of consumption as in Canada. Most experts are convinced that nuclear power is on its way. How will hydro power be integrated in such rapidly expanding systems?

In countries where water for irrigation has to be stored in large reservoirs the demand for more hydro power will develop in parallel with the expanding irrigation. In areas like India, Pakistan, Africa and South America hydro power—often linked to irrigation—will for many years be the most favoured source of electrical energy. Local conditions, like cheap labour, foreign currency regulations, favourable topographical or climatic conditions may accentuate this trend.

It is a general belief that in addition to the cases just mentioned hydro power is still one of the favoured potential sources of energy for the future. To strengthen this belief a general analysis of the economic structure of electric power generation will be attempted, showing the price structure of hydro power to be well in line with the rest of the power generating industry.

2. A team of professors of Harvard University is presently investigating diverse aspects of "River System Planning" a problem sometimes related to power generation. During their research they have considered three methods of approach to their own problem:

(*a*) Development of specific schemes, comparison of several alternatives and final choice based on sound engineering principles. This is the classical method used in hydro power design.

(*b*) Analysis of a whole set of problems by simulation on computing machinery. This may be the method of the future.

(*c*) The method of "Simple Mathematical Models" was finally considered. The team of professors found this to be—for the time being—the most suitable method of investigation for their River System Planning problem.

A similar method of "Simple Mathematical Models" has recently been used with success for the analysis of the economics of pumped storage. It soon became apparent that a similar approach could be used for investigating the more general problem of the "Integration of Hydro Power in larger expanding Systems". Most of the problems of power generation and of prices and costs are either linear relations or can be reduced to simple integrations of surface areas and, therefore, quite suitable to be analysed with the help of simple mathematical models.

This third method is the one chosen for this paper. In practical cases the three methods may have to be combined. Results obtained with one method will help in developing the others.

System Load Factor Analysis: Theorem of Energy Areas

I. System Analysis

The following section is an attempt to represent by simple mathematical means including equations and diagrams, some of the main problems which are encountered when dealing with the integration of hydro power into large electric systems and the balancing of base load and peak load power generation. This mathematical analysis is intended as an introduction to the problems of adapting hydro power to the future requirements of large systems.

1. *System Load Factor:*

The point of departure for any general or parti-

cular study of this nature will always be the analysis of the system into which the new scheme has to be introduced and of the requirements it must satisfy. A general method of analysis has been developed which is based on the analysis of a series of load duration curves and of the load factors of the system and its components. It can be shown that the balance sheet for the power and energy production by a group of stations depends mainly on these load factors (Fig. 1); so do the price of energy and generating costs.

The load factor θ is defined (Fig. 1) by:

$$\theta=(1/MT)\int_0^T Ndt$$

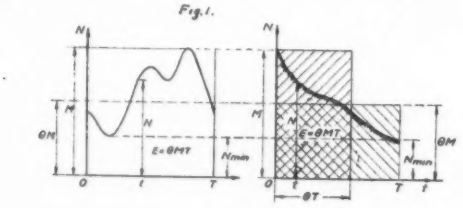
It shows the percentage of time θ during which a station with installed capacity M would work at full capacity to generate the total energy $\int_0^T Ndt$ over a period of T. This total energy is equal to the shaded area under the duration curve in Fig. 1 and is also equal to the area of the rectangle $M\theta T$.

The load factor θ_s of a large system is a quantity which varies slowly with time and its trend can be predicted several years ahead. A method of price analysis which is based mainly or entirely on load factors will afford fairly reliable economic predictions. It will be shown that a knowledge of the system load factor, and of the load factors of its component parts, are indispensable for the discussion of the economics of particular schemes and projects and especially of pumped storage.

2. *Details of the System Load Factor Analysis:**

Any electric power system with a total installed capacity M and a system load factor θs can be subdivided into system components characterised by their installed capacities N_1, N_2, N_3... N_i... and load factors θ_1, θ_2, θ_3... θ_i... over a period T. The following general theorems can be demonstrated, using the system of duration curves shown in Figs. 2 and 3.

Fig. 1.



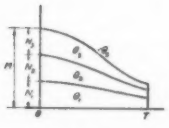


Fig. 2.

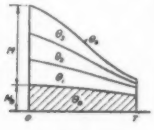


Fig. 3.

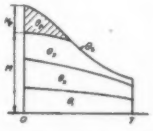


Fig. 4.

* Details of the mathematical development which is summarised in the succeeding paragraph can be found in "Water Power," February/March 1957 and June, July, August 1958 and in the "Proceedings of the Institution of Civil Engineers" Vol. 14 for November 1959.

1. There is a linear relationship between θ_s and θ_1, θ_2, θ_3... θ_i... depending only on N_1/M, N_2/M, N_3/M... N_i/M... This linear relationship does not depend on the shape of the load duration curve derived from the load/time curves of the system. Fig. 2 yields:

$$\theta_s M=\theta_1 N_1+\theta_2 N_2+\ldots.+\theta_i N_i\ldots. \quad (1)$$

2. Any new source of power with capacity N_B and load factor θ_B added to an existing system $M\theta_s$ may change the load conditions in a system component $N_i\theta_i$. An equation similar to equation (1) can be written for this case

$$\theta_s (M+N_B) =\theta_1 N_1+\theta_2 N_2+\ldots.+ (\theta_i+\Delta\theta_i) N_i+ \ldots.\theta_B N_B \quad (2)$$

The condition for "no change" to occur in the existing system (Figs. 2 and 3) is obtained when

$$\Delta\theta_i=0 \quad \text{and} \quad \theta_B=\theta_s. \quad (3)$$

In the more general case

$$\theta_B=\theta_s-(N_i/N_B)\,\Delta\theta_i \quad (4)$$

where $\Delta\theta_i$ is the change occurring in the system $N_i\theta_i$ owing to the addition of a new source of energy $N_B\theta_B$. This fundamental relationship permits us to relate the price analysis of the new system to the price changes occurring in the component "i". The proposition can be generalised to include several "i" components.

When a new peak load station is being introduced in the electric system a similar equation can be developed (See Figure 4.)

$$\theta_P=\theta_s+(N_i/N_P)\,\Delta\theta_i$$

Usually θ_B will be larger than θs and $\Delta\theta$ is to be subtracted from θi in the case of base load being added to the system; θi will then drop to a lower value. On the contrary when peak load is being added, θ_P is smaller than θ_s and $\Delta\theta_i$ is positive. The load factor of the station N_i increases to $\theta_i+\Delta\theta_i$.

Depending on the price structure of the system, these variations of θ_i may be favourable or not and have to be accounted for on one side or the other of the balance sheet.

The case of a run-of-river station requires special comments which will be given later.

The theorem (1) is called the "theorem of energy areas" and it can be shown that it is generally valid.

3. *The Soschinski Function:*

More detailed investigation, especially when it concerns pumped storage, requires an exact knowledge of the actual load duration curve of the system. For the requirements of the theoretical system analysis, the actual load duration curve can be replaced by a convenient mathematical curve, which can be integrated.

The suggested choice is for the so called Soschinski

function, which is found to match actual duration curves in a great number of cases, particularly those for large electric generating systems. This function shows that the load N at time t ($o<t<T$) depends only on θ and $\theta_o=m/M$, where M is the maximum required capacity and m the minimum required load (Figs. 5 and 6). The Soschinski function is:

$$N=M\,[1-(1-\theta_o)\,t^{(\theta-\theta_o)/(1-\theta)}] \qquad (5)$$

Both θ and θ_o can be predicted from a number of

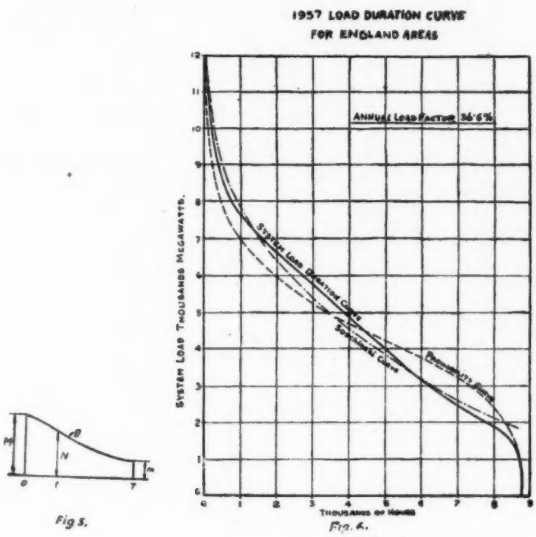


Fig. 6.

actual duration curves. Usually θ_o can be taken as $\theta_o=\theta^2$ to $\theta^{2.5}$ (exceptionally it may be θ^3).

II. *The Price Problem*

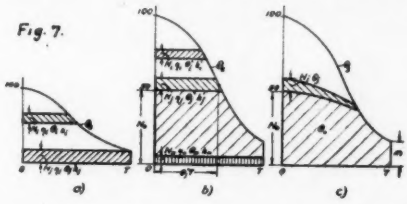
The generating cost of one kWh of electric energy can be represented by a linear equation like

$$k=\frac{Kr}{\theta T}+k_e \qquad (6)$$

where k is the cost per kWh generated, K the capital cost per kW installed capacity, r the rate of interest, (which, in this case, are calculated to include all the expenses directly proportional to the installed capacity N), k_e is a factor which summarises all those cost elements which do not depend on N but on the energy (like fuel costs). θ is the load factor and T=8760 hours per year.

The Economic Commission for Europe (United Nations*) have produced a most interesting document analysing the factors K, r and k_e for several European countries and for the U.S.A. All the prices are compared with the costs of a standard thermal station and expressed in relative values, a method which gives permanent interest to this inquiry, as it is independent of possible variations of the money of the country under investigation.

When splitting up an electric system ($M\theta_s$) into partial systems ($N_i\theta_i$) and assigning to each its own generating cost k_i per kWh, it is possible to calculate the overall generating cost of the system at a certain time and to follow the evolution of costs when the system expands over the years, as shown in Fig. 7.



Equations of the type (6) can be useful when comparing different sources of power generation and establishing the costs and unit prices for different possible combinations of the sources.

1. A first problem to be solved concerns the differential generating costs of base load and of peak load from the same energy source. Let us assume that a system with capacity M is characterised by a load factor θ_s. When this load factor is $\theta=1$, the price of the energy is:

$$k_o=\frac{Kr}{T}+k_e$$

per unit, a figure to be used for easy comparison. The same system now working with a load factor $\theta_s<1$ can be split in three sub-sections (Fig. 8):

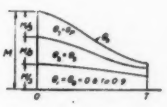


Fig. 8.

$N_1=M/3$ working, for example, at a load factor $\theta_B=0.9$ or 0.8

$N_2=M/3$ working at a load factor $\theta_2=\theta_s$ and

$N_3=M/3$ working at a load factor $\theta_3=\theta_p$ to be calculated using equation (1).

The relative cost of the peak energy is then*):

$$\frac{k_p}{k_o}=\frac{\dfrac{Kr}{\theta_p T k_e}+1}{\dfrac{Kr}{Tk_e}+1} \qquad (7)$$

Diagram Figure 9 and Table I show how this relative price varies. This price ratio depends on θ_s and on the ratio K_r/Tk_e (which may vary from about

* Economic Commission for Europe (United Nations). Power Division. Publication E. P/47, Geneva, May 18, 1953.

* A more detailed paper giving correct demonstrations of the formulae used here is published in *British Power Engineering* Sept./Oct. 1960.

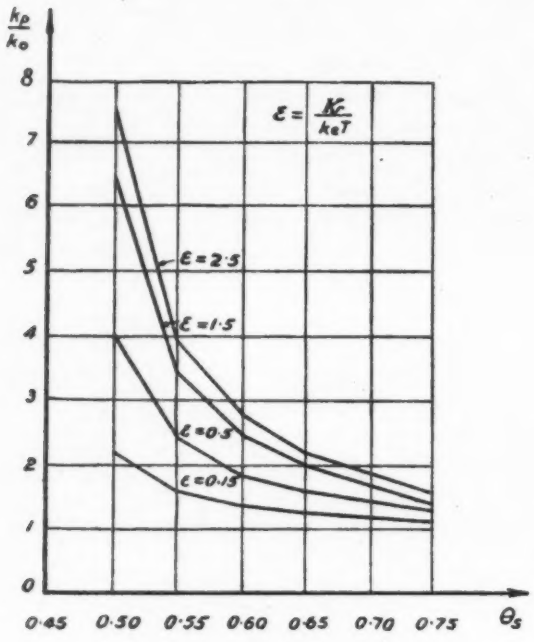


Fig. 9.

0.15 for gas fired turbines to 0.2—0.5 for steam and 1.5 to 2.5 for nuclear stations).

It is certainly worth while comparing the prices from Table I with the actual market prices of hydro power generated in the European Alps. They are given for each month for peak load, average load and base load in Table II.

There are obvious similarities between figures in Table I and in Table II showing similar trends for higher prices for peak load.

2. Another problem of interest is the comparison of the price $k = \frac{K_r}{\theta_s T} + k_e$ of energy generation in a system ($M_1\theta_s$) consisting of one source only with the generating price k_{B+P} of a system with two sources, the peak load being from a different source, with generating price k_p.

It can be shown that:

$$\frac{k_{B+P}}{k} = \frac{k_p \theta_p N_p}{k \theta_s M} + \frac{\left[\frac{K_r}{\theta_B T k_e} + 1\right]}{\left[\frac{K_r}{\theta_s T k_e} + 1\right]} \frac{\theta_B N_B}{\theta_s M} \qquad (8)$$

where k_p, k, N_B, N_p and θ_B are supposed to be known, θ_p is calculated with equation (1) and substitution in equation (8) yields k_{B+P}/k.

For the special case of the term k_e for base load being negligible (water power) equation (8) becomes

$$\frac{k_{B+p}}{k} = \frac{k_p \theta_p N_p}{k \theta_s M} + \frac{N_B}{M} \qquad (8a)$$

This equation has been amply discussed in a former paper dealing with the special problem of pumped storage*. Fig. 10 shows how the ratio k_{B+P}/k varies in this particular case.

Assuming at the limit equality of prices $k_{B+p}=k$ the limit value k_p/k can be found for this to occur.

Table I.

Relative Peak Load prices k_p/k_e (equation (7))

One source of energy for different θ_p, θ_s and $K_r/k_e T$ values.

θ_s =	0·45	0·50	0·55	0·60	0·65	0·75
θ_p =	0	0·10	0·20	0·30	0·40	0·60
$K_r/k_e T$ = 0·15	—	2·18	1·52	1·30	1·20	1·04
" = 0·50	—	4·0	2·34	1·78	1·5	1·22
" = 1·5	—	6·4	3·4	2·4	1·9	1·4
" = 2·5	—	7·42	3·87	2·67	2·08	1·47

Table II

Market prices for electrig energy at centre of Consumption

(Switzerland 1956) in penee per KWt.

Winter.

	5 h/day 120 h/month	additional 4 h/day 95 h/month	2nd additional 4 h/day 95 h/month
October	·88	·76	·64
November	·98	·84	·70
December	1·08	·92	·76
January	1·1	·94	·78
February	1·08	·92	·76
March	1·0	·86	·72

Summer

	2½h/day 65 h/month	additional 3½ h/day 85 h/month	2nd additional 4 h/day 90 h/month
April	·86	·72	·62
May	·64	·50	·40
June	·52	·38	·28
July	·52	·38	·28
August	·62	·48	·38
September	·74	·60	·50

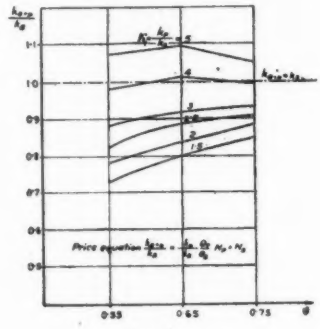


Fig. 10.

* C. Jaeger. Water Power—June, July, August 1958.

It is:

$$\frac{k_p}{k} = \frac{\theta_s M}{\theta_p N_P}\left\{1 - \frac{\theta_B N_B}{\theta_s M}\left[\frac{\frac{Kr}{\theta_B Tk_e}+1}{\frac{Kr}{\theta_s Tk_e}+1}\right]\right\} \qquad (9)$$

which is represented graphically on diagram Fig. 11.

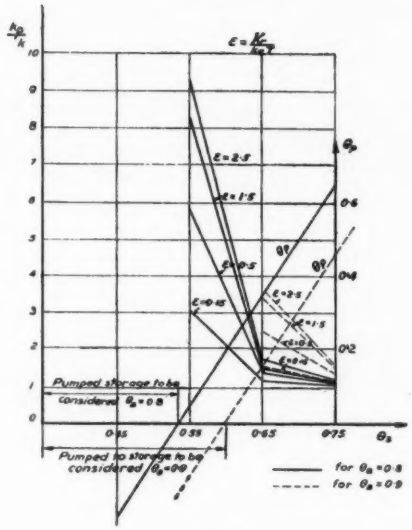


Fig. 11.

3. Starting from these simple and very general price equations, many other price problems can be discussed. One of the most interesting, estimates the additional amount of money ΔK which it is economical to spend per additional kW when a power station with capacity N is enlarged to a capacity $N+\Delta N$.

4. The combined use of equations (1) and (5) allows the discussion of a variety of problems of costs and prices. They indicate how prices can vary with the load factors θ or θ_s and with the ratio Kr/Tk_e for different sources of power. The "simple mathemtical model method" yields interesting results. In short, it has been shown that, whatever the source of energy there are wide price variations for base load and peak load generation, mainly depending on the load factors.

This price analysis based on the "simple mathematical model method" can be developed further by introducing additional models describing correctly the power generation by run-of-river stations, by storage reservoirs or by pumped storage. This more specialised approach will, in future, be the starting point for many detailed researches on computing machines.

It is known that in many countries the cost for the base load hydro power energy compares not unfavourably with other sources of energy. Under favourable local circumstances hydro power can even be cheaper than steam power.

The price ratio for hydro peak load compared to hydro base load is much the same as for other sources of energy. Currently a price for hydro peak load about 2.5 or 3 times dearer than base load seems acceptable. There are indications that on a cost and price basis the present balance between hydro power energy and capacity and other sources of energy can be maintained.

On the other hand, there are strong indications that important changes in the structure of the whole industry may gradually occur, which require further investigation.

This is worth further discussion.

Integration of hydro power into large expanding electric systems: Design problems

The first three chapters of this paper are devoted to developing a simple method of analysing general problems of power, installed capacity and generated energy and combining different sources of energy with different price characteristics in such a way as to obtain the energy and capacity, required by the demand, at a minimum cost.

This analysis shows the hydro power industry to be well adapted to load and energy requirements within the price pattern to be expected for the different types of energy in the immediate future.

On the other hand when the more characteristic hydro power designs in leading modern countries are being considered, the impression is gained that the electric generating industry as a whole evolves steadily and slowly.

Conventional hydro power designs, for many years to come, will still be an often preferred source of energy and capacity. There are no signs of sudden important changes.

Careful reviewing of new possibilities is nevertheless imperative. Some basic rethinking is required mainly to face a new balance developing between capacity in kW and energy in kWh. New methods have to be devised for dealing with the fluctuating daily demand for electric power.

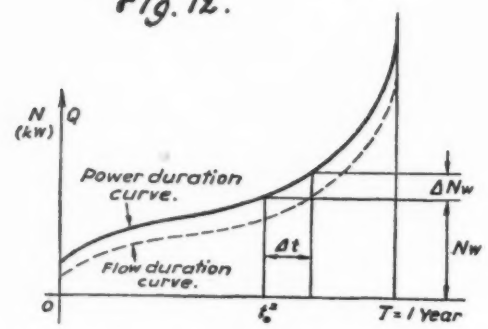
Run-of-river stations:

1. A river can be characterised by its flow duration curve and a run-of-river station with capacity N_B developed on this river will be described correctly by a similar power duration curve (Fig. 12). Let E_o be the generated energy, then

$$\theta_o^* = E_o/TN_B$$

is a "generation factor" which characterises a run-of-river station as the load factor θ characterises a power demand curve. It is to be expected that the peak demand in the system will not coincide with the peak of the power generation in the station considered.

Fig. 12.



The opposite is often likely to occur as shown in Fig. 13a and b. If the system and the river power were represented by ordinary load duration curve, the required capacity of the power stations other than the run-of-river station would be (Fig. 13c).

$$N_2 = M - N_B$$

whereas on Fig. 13 a and b it is clear that

$$M_2 > N_2$$

$$M_2\theta_2^* = M\theta_s - N_B\theta_o^*$$

now yields θ_2^* lower than the conventional θ_2 value given by Fig. 13c, where $N_2\theta_2 = M\theta_s - N_B\theta_o = M_2\theta_2^*$.

It follows that whenever a run-of-river station shows a decreased generating capacity at the very moment when maximum power capacity is required by the whole system the total yearly energy balance is not impaired, provided the total capacity $M_2 > N_2$ of all other power stations is sufficient to cover the total demand. It is essential to realise that the monthly sequence of water discharges is then immaterial, but base load energy prices from run-of-river stations have to be charged with the cost of the additional standby capacity $M_2 - N_2$

In practice these facts have been implicitly recognised for decades by energy producers who used to design run-of-river stations for the water discharge available 50 or 100 days a year in the 1910s, then went up to 180 days in about 1920 and to 240 in 1940 and now are going beyond this figure. As shown, additional capacity has to be provided for elsewhere. In many cases well designed storage stations branched on the same electric system produce the necessary capacity.

There is also a growing tendency for utilising even limited storage capacity available on rivers to get out of them more kilowatts, even if the total yearly energy output in kWh cannot be increased markedly.

In this respect it is worth mentioning some recent publications favouring either the use of chains of run-of-river stations built on the same river or even using pumped storage on a chain of such stations as shown on Fig. 13*. The economics of such mixed power developments were studied elsewhere. Such power combinations definitely deserve the attention of designers.

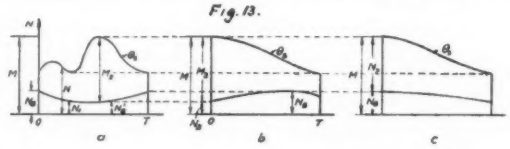
These new suggestions for more kW to be installed on rivers are linked with the future development of nuclear energy. If, in the next ten to fifteen years, the general price pattern of nuclear power remains what it is now, much will depend on the ability of hydro power engineers to adapt their own designs to the necessity of getting cheap power capacity to balance the nuclear base load energy.

2. *Storage Capacity:*

In the previous paragraphs on run-of-river stations the trend towards higher installed capacity has been underlined and reasons for this trend to develop further have been given. Similar remarks apply to storage plants. Figures can be mentioned showing how over a short period the load factor of power stations with large storage reservoirs in the Swiss Alps has fallen from about 0.40 to about 0.25, the general topographical and hydrological conditions for the hydro power developments being about the same.**A few years ago, high head power stations with large reservoirs were designed for seasonal power storage. Water is accumulated during the Summer to balance the power production during the dry Winter months. More recently lower load factors have been adopted for similar power developments, in view of generating daily peak load power for balancing future nuclear base load power generated at night. Daily storage is being combined with seasonal storage. This trend is the more remarkable as the nuclear power stations are still at the design stage, whereas some of the high head stations mentioned here have been running for about a year.

The new trend in design is worth further analysis. It can be shown that for problems of this type mathematical models can be developed for the

Fig. 13.



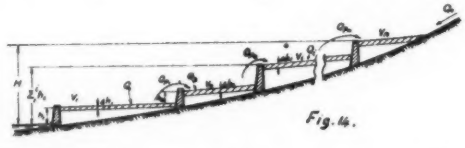


Fig. 14.

* C. Jaeger. Water Power, June, July, August 1958 and Proceedings Inst. Civil Engineers Vol. 14. Nov. 1959.

* C. Jaeger. Proceed. Inst. Civil Eng. Vol. 14. pp. 291—318. Nov. 1959.

**The stations considered here are: Maggia power development (1952), Blenio power development (1958/59) and Hinter-Rhein (1959).—Other power developments with low θ values are Schuchsee werke (1929-53) with θ=0.15 Glockner Kaprun (1949-57) with θ=0.24, Loch Sloy (1950) with θ about 0.12. etc. Detailed figures were submitted to the World Power Conference, Madrid June 1960.

discussion of storage problems and of losses in conduits.

The correct estimate of the required storage capacity, the best method of using it and the estimate of losses are main factors in determining the price levels of stored hydraulic energy.

A basic fact soon emerges from this more theoretical analysis. High dams and large storage reservoirs are major items in the costs of storage schemes. When tunnels and conduit lengths can be maintained within reasonable limits the additional cost ΔK for additional capacity ΔN is relatively low. High head storage schemes with great installed capacity will in future play an increasingly important function in the power and energy balance of expanding systems. The theoretical analysis entirely justifies the modern trends in the design of large stations.

These are problems to which more and more attention will have to be devoted in the near future. The success of this research for additional capacity will often depend on tunnel and conduit losses and on power transmission costs at distances beyond 100 miles. These have to be carefully considered when introduced into the more detailed mathematical models.

3. *Pumped Storage:*

When dealing with run-of-river stations and with storage capacity, pumped storage was repeatedly mentioned in connection with the shifting of energy either from night to day or from the wet season to the dry season. Implicitly it was indicated that pumped storage can be used for increasing the peak capacity of a system.

In the pre-war period, a limited number of pumped storage schemes were designed and built. In most cases seasonal pumped storage was considered. Real day and night systems were the exception. Then, in the period after the last war, more and more powerful storage systems were built and commissioned: most of them of the daily storage type. These new developments in Germany, Luxemburg, Great Britain, Canada and the United States are indications that the electric power industry is evolving on slightly different lines than before the war.

The research made to explain and estimate the importance of this trend* was the point of departure of the wider effort outlined here.

IV. Conclusions

In the past hydro power has been one of the main sources of energy. Balanced systems including run-of-river stations and large water storage systems have been designed which generate more or less constant energy over the whole hydrological year. Seasonal storage of power is an essential feature of such systems. Examples from Italy, Austria, Switzerland, Scandinavia, Canada can be analysed to show how such systems work.

There is now a growing need to consider the more varied tasks to be assigned to hydro power when integrated in diversified electric systems where steam generated or nuclear generated power may produce the base load. Hydro power will then be analysed not only as a source of cheap energy but also as a possible way of securing cheap additional capacity.

A method had to be devised for analysing rapidly and accurately the main aspects of a most intricate problem. The "mathematical model method" was shown to give reliable answers to a number of vital problems.

It is not expected that this method will supersede the more detailed analysis on modern calculating machines, but the "mathematical model method" saves time, helps in preparing the programming on the computers and checking the main results.

It is desirable that this method be further developed.

* C. Jaeger. Water Power, February/March 1957 and June, July, August, 1958. Indian Journal of Power and River Valley Development. Vol. IX, No. 7, July 1959. 1-7.

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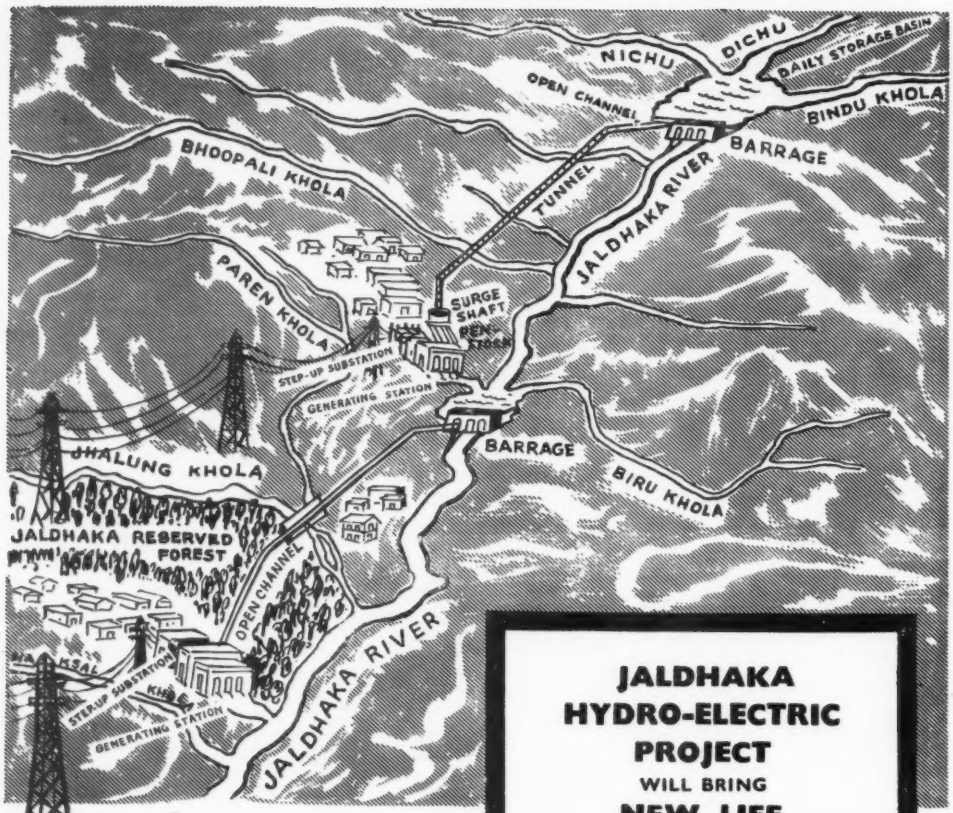
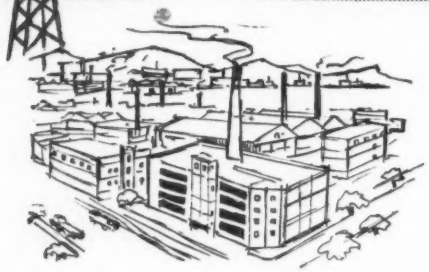




JALDHAKA HYDRO-ELECTRIC PROJECT

WILL BRING

NEW LIFE

TO THE NORTHERN DISTRICTS OF

WEST BENGAL

Work is steadily progressing in the hilly northern districts of West Bengal, where more than 1,500 people are engaged in giving shape to the first major power project in North Bengal—the Jaldhaka Hydro-electric Scheme—initiated by the West Bengal State Electricity Board.

This project, which will cost about Rs. 4.45 crore will supply a firm power of 18,000 KW for urban and industrial loads and an additional seasonal power of 18,000 KW during the eight months from April to November, peak period of work in tea plantations. The power supply will cover a total area of 2,000 sq. miles in the districts of Darjeeling, Jalpaiguri and Cooch-Behar. Initially serving 19 towns, the water-power resources, thus harnessed, will ultimately benefit 40 towns.

The project encompasses a comprehensive approach by arranging for roads, dwelling sites, schools, hospitals, post office, telephones and other amenities to attract sufficient working personnel.

With the completion of the project and availability of electrical power at a moderate cost, a wilderness will pulsate with life for the economic and industrial benefits of the people contributing to the building of a ***better Bengal.***

JALDHAKA PROJECT

WEST BENGAL GOVERNMENT

WBG-72

N. D. Gulhati
Additional Secretary,
Ministry of Irrigation and Power, India

Indus Waters Treaty 1960

WITH THE INDEPENDENCE OF INDIA IN 1947, THE country was simultaneously divided into two independent States of India and Pakistan. This division raised various problems; many of these were decided at the time but some remained unsolved. The controversy regarding the waters of the Indus system of rivers has now been resolved after 12 years of patient negotiations. Since 1952, the International Bank for Reconstruction and Development played a mediatory and a positively helpful role towards this settlement.

The problem arose immediately after partition with regard to a relatively small matter, viz., continuance of the supply of water to two of the numerous irrigation canals in Pakistan. Unlike other canals which lay wholly in Pakistan, these two canals had their headworks and upper reaches in Indian territory. But before long the problem logically turned into one requiring an overall and long-term solution, *viz.*, the division of the waters of the Indus system of rivers and agreement between the two countries regarding their rights and obligations relating to the use of these waters.

Every controversy between two independent nations is generally viewed as a political dispute. But the first step towards a solution of the Indus waters controversy was taken in March 1952 when the Parties accepted the recommendation of Mr. Eugene R. Black, President of the International Bank for Reconstruction and Development to attempt to find a solution of the problem, by agreement, on a functional—not political—plane and without regard to other controversies between the two countries. The Prime Minister of India had earlier stated that this was essentially an engineering problem, also a human problem, and should be approached as such. It was this approach which has largely been responsible for the fact that it has been possible to find an agreed solution of one of the largest, most difficult and complicated international water disputes in the World in a relatively short period of eight years. Many smaller disputes, much simpler in nature, have defied, and are continuing to defy, solution for a much longer period.

To understand the nature of the agreement reached between India and Pakistan, and incorporated in the Indus Water Treaty 1960, it is necessary first to note some important facts about the Indus Basin.

Important particulars of the Indus Basin

The average annual flow of the Indus system of rivers, as they emerge from the Himalayas, is about 168 million acre-feet, about the same as that of the Columbia running through the U.S.A. and Canada, about twice that of the Nile and about 10 times as large as the flow of the river Colorado running through the U.S.A. and Mexico. The mean flow of each river is as follows:

Name of river	*Mean volume of flow*		
	rabi (Oct.-Mar.)	*kharif* (Apl.-Sept.)	Annual
	million acre-feet		
Indus (at Kalabagh)	13.0	76.5	89.5
Jhelum (at Mangla)	4.5	18.1	22.6
Chenab (at Merala)	3.7	19.8	23.5
Ravi (at Madhopur)	1.2	5.2	6.4
Beas (at Mandi-Plain)	2.4	10.5	12.9
Sutlej (at Rupar)	2.0	11.5	13.5
Total	26.8	141.6	168.4

There is little contribution to river flow from the catchment below the points mentioned above.

The Indus basin contains some of the world's oldest irrigated areas. This irrigation, however, was mainly by inundation, mostly natural but in some places assisted by indigenous canals leading the flood waters some distance away from the river banks. From the middle of the 19th century onwards, a number of large and highly developed canal system were constructed from the Indus rivers. By 1947, about 26 million acres of arid land were irrigated annually from these canals, representing the largest irrigated area in the World from any one river system. All these canals were based entirely on the flow waters of the rivers. No storage reservoir had been constructed in the basin till that time. Thus, almost the entire *rabi* flow of all the

rivers, except for a small quantity on the Indus, and a large part of the *kharif* flow had been applied to irrigation. Some further development was possible from the flow-waters of the Indus, the Jhelum and the Chenab but for most part further development was possible only by the construction of storage reservoirs.

The new political boundary between India and Pakistan drawn in 1947 placed in Pakistan about twenty-one million acres of the area irrigated from the Indus rivers and placed in India only five million acres of such area. Most of the irrigation canals came to lie in Pakistan and only a few in India. But the population dependent on the Indus water was split about 25 millions in Pakistan and 21 millions in India.

For various reasons, technical, economic and political, irrigation developments from the Indus rivers until independence were largely in the area now in Pakistan. Millions of acres of arid land in the south-eastern part of the basin, which came to lie in India, were waiting to be developed when the new political boundary was drawn. In the areas already developed whether in India or in Pakistan additional water use had still to be developed and some new developments were also possible from the Indus in the areas falling in Pakistan.

Of the 168 M.A.F. of annual flow in the Indus system of rivers, only 9 M.A.F. was used in canals in India and about 66 M.A.F. by canals in Pakistan. About 75 M.A.F. was being escaped into the Arabian Sea, a large part during the three flood months of July, August and September. About 18 M.A.F. was being lost in the long length of the rivers.

Although the upper reaches of all the principal rivers of the Indus system lie in India, the Indo-Pakistan boundary in so situated that, for use in plains, India can divert mainly the waters of the Ravi, the Beas and the Sutlej and only a small part of the Chenab. On the other hand, about 50 per cent of the waters of the Ravi and about 80 per cent of the flow of the Beas, for about nine months in the year, were being used in canals in Pakistan. Out of the total flow of about 33.0 M.A.F. of these three rivers, about 12 M.A.F. was being released for these canals in Pakistan.

The Treaty

In the Preamble to the Treaty, the Parties have set out their objective: "The Government of India and the Government of Pakistan, being equally desirous of attaining the most complete and satisfactory utilisation of the waters of the Indus system of rivers and recognising the need, therefore, of fixing and delimiting, in a spirit of goodwill and friendship, the rights and obligations of each in relation to the other concerning the use of these waters and of making provision for the settlement, in a cooperative spirit, of all such questions as may hereafter arise in regard to the interpretation or application of the provisions agreed upon herein, have resolved to conclude a Treaty in furtherarnce of these objectives....."

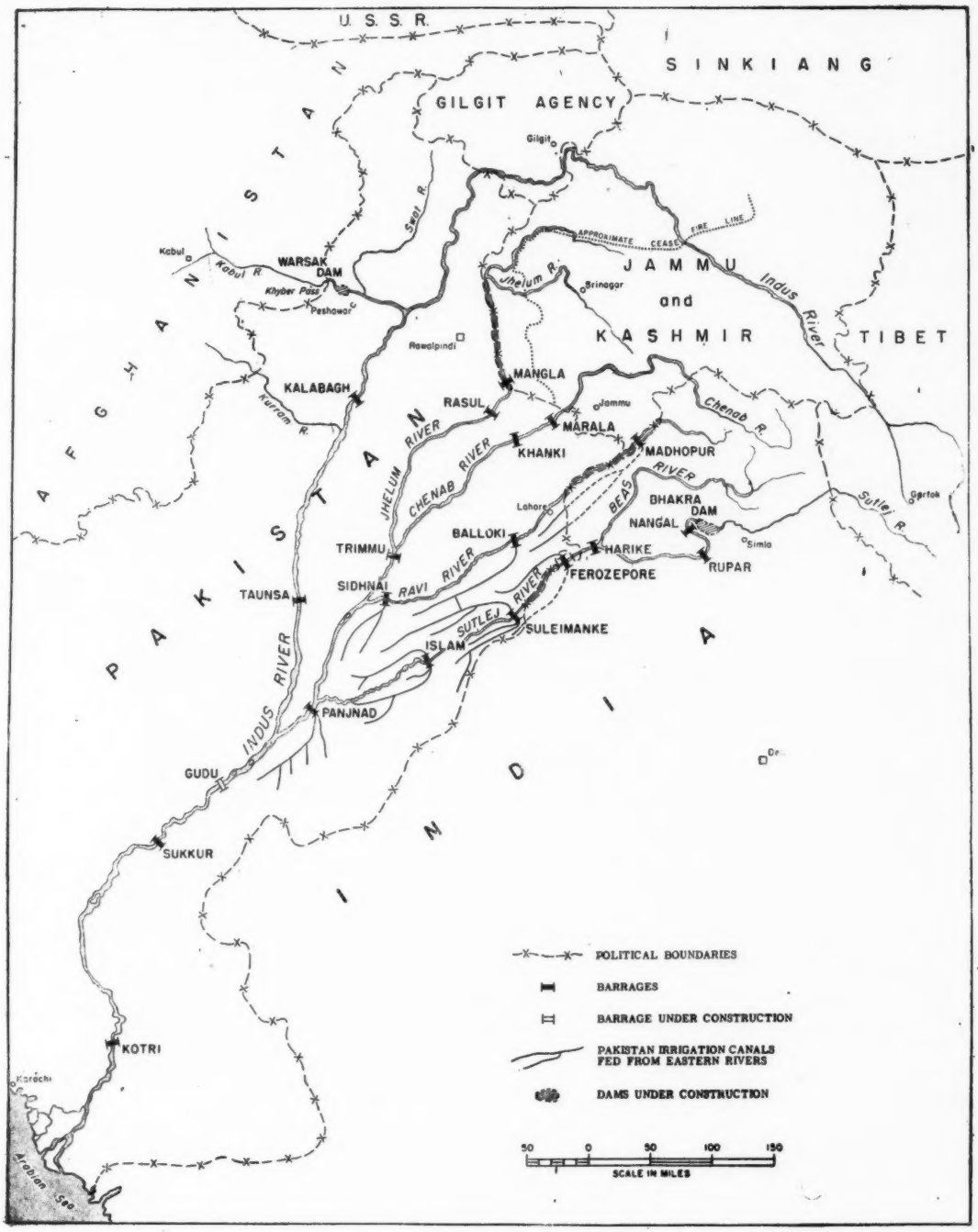
The most important feature of the Treaty is the division of the waters between the two countries. The Parties have agreed that all the waters of the Eastern Rivers, *viz*, the Sutlej, the Beas and the Ravi, should be available for unrestricted use by India. On the other hand, India has agreed to limit its uses from the waters of the Western Rivers, *viz*, the Indus, the Jhelum and the Chenab to those specified in the Treaty and to let flow the remaining waters for use by Pakistan.

The uses by India from the Western Rivers in their upper hilly catchments, with elevations extending up to 11,000 feet or more, could not be stated in terms of million acre-feet of water. India will, however, have full freedom to use these waters for domestic, municipal and industrial purposes, non-consumptive uses and for flood control etc. India will have full freedom to develop hydro-electric power on the Western Rivers provided some specified design criteria are observed. Indian can store on the Western Rivers about 3 M.A.F. of water for various uses specified in the Treaty. About one million acres already irrigated in India from the Western Rivers will continue to receive irrigation supplies as heretofore, and India will have the right to develop new irrigation facilities for another 0.7 million acres from these rivers within their catchments in India.

In other words, the Parties have agreed that India may develop for its use about 33 M.A.F. of the waters of the Eastern Rivers; and such waters of these rivers (about 12 M.A.F.) as were previously being released for Pakistan canals will now be replaced by Pakistan by withdrawals from the Western Rivers.

Pakistan will get about 135 M.A.F. of the waters of the Western Rivers less the quantity consumed by India in the uses specified in the Treaty. This quantity will be a small part of the total waters which may be diverted for irrigation or otherwise used in India as a large part of these waters will re-appear in the rivers lower down as return flow.

There shall be a Transition Period of 10 years under certain conditions, can be extended to 13 years. During this period, India will continue to deliver to Pakistan some supplies from the Eastern Rivers, in accordance with detailed regulations in the Treaty. The principle underlying these regulations is that the withdrawals to be made by India for new developments, in so far as these withdrawals would reduce



Map of the Indus Basin.

supplies to Pakistan canals, are related to Pakistan's ability to replace these withdrawals from the Western Rivers.

Pakistan has agreed to use its best endeavours to construct and bring into operation, as early as possible, that part of a system of works which will accomplish the replacement, from the Western Rivers, of water supplies for irrigation canals in Pakistan which have been dependent on the Eastern Rivers.

India has agreed to pay a sum of pounds sterling 62 million towards the costs of the replacement element of the system of works to be undertaken by Pakistan on the Western Rivers.

The Treaty sets out the mutual obligations which the parties have accepted with regard to the operation of river works, maintenance of river channels, pollution, floating timber etc. and to the exchange of data of river flow and canal withdrawals etc.

The parties have agreed to establish a Permanent Indus Commission consisting of an Indian Commissioner and a Pakistan Commissioner who will ordinarily be high ranking engineers. The Commission will set up and maintain cooperative arrangements for the implementation of the Treaty and will try to resolve by agreement such differences and disputes as may arise in regard to the implementation of the Treaty.

The Treaty also sets out detailed procedures for resolving such differences and disputes as may not be resolved by the Permanent Indus Commission. Relatively small differences on specified technical matters shall be settled by the decision of a Neutral Expert but disputes involving interpretation of the Treaty or alleged violation of its provisions will be referred to the two Governments for settlement either directly or with the help of a mediator and in the last resort by reference to an Arbitral Tribunal to be set up in each case.

Extensive Developments in the Indus Basin

The conclusion of this Treaty opens a new chapter in the development of the waters of the Indus system of rivers. Each country is free to develop the waters allocated to it, in accordance with its needs and resources.

India is already going ahead with the Bhakra Nangal Project for hydro-electric development and for the irrigation of about four million acres of land in south east Punjab and Rajasthan. Work is also proceeding on the construction of the Rajasthan Canal with a capacity at head of 18,500 cusecs for the irrigation of about three million acres in the Rajasthan desert. This Treaty assures adequate supplies to these canals when they are completed. India is also going to undertake the construction of a dam on the Beas which will store the flood waters of the Beas for hydro-electric development and for use in the Rajasthan canal and in south-east Punjab. Some financial assistance has been promised to India by the U.S. Government and the World Bank to meet the foreign exchange costs of the Beas Dam.

Pakistan is going to embark upon one of the largest water resource development programmes ever to be undertaken in the World. In addition to the replacement mentioned above, the system of works that is being undertaken will provide for further substantial irrigation development and hydro-electric potential in Pakistan. These works, which will cost about 900 million dollars, include eight link canals, nearly 400 miles in total length, two earthfill storage dams with live capacity of 4.75 M.A.F. and 4.2 M.A.F., a power station of 300,000 kW, three new barrages, a large number of tubewells and drains to overcome waterlogging and salinity in 2.5 million acres of irrigated land in Pakistan. The costs of these works in Pakistan have almost entirely been underwritten by the financial contribution by India, referred to above, and large financial assistance promised by a number of friendly countries and the World Bank.

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The Disappearance of the Civil Engineer

ONCE UPON A TIME THERE WAS A PROFESSIONAL MAN, called The Engineer. He was a Civil Engineer, as opposed to a military engineer, and could answer all the practical questions of his wide trade. He was made into an engineer by a few years of training, which followed the long, active and scholarly years of his high-school. He was a humanist interested in technical questions, and he was an artist. He really learned his trade as an apprentice in the office or shop of an older Civil Engineer. He was familiar with a few fundamental ideas and some basic formulas. He could manipulate arithmetic without fault and relied on his experience and that of his predecessors, gathered in simple but useful manuals, to solve difficult and costly problems. He was not hampered by an inferiority complex when tackling problems involving many variables, because he relied above all on his commonsense and on his physical intuition. His physical intuition could carry him a long way since most of the situations he was confronted with were visual and could be grasped by the physical eye. He was highly respected by his client because he could save large amounts of money, or time, or human effort. He was the soul of the industrial revolution and the world he shaped gave humanity, for a while, dreams of a new Eden.

The Civil Engineer had no delusions about himself: he never thought of his activities as being scientific. He was glad to be familiar with a few of the scientific discoveries made in the past, and to be able to squeeze from them some practical results of importance to his client. But he was also a dreamer; he would change the face of the earth by his ideas and methods, he would put nature and its forces at the service of humanity, he would conquer gravity and friction and distance and time. He was the most practical dreamer the world had ever seen. And as all dreamers, he was a staunch individualist; he believed in himself and in hard work, in cautious daring and in responsibility. Also, like all dreamers, he did not believe in money; he was contented with a modest salary and a large amount of respect from his fellowmen.

But then something happened and the Engineer, the secure, respected Civil Engineer received a tremendous jolt to both his faith and his respectability. A few members of his clan, instead of keeping their feet on the ground as they were supposed to do, began reading, and studying and working in a new high-falutin field, that had to do with unseen forces and ununderstandable formulas. It was called "electricity" at first, and then electrical engineering. It was a strange game where things appeared to happen by magic; but some said, this new magic could be explained by mathematics, not the good old arithmetic and trigonometry (not even the complicated trigonometry used in topography and geodesy) but, of all things, the calculus. This was something physicists, like Newton, or "pure" mathematicians could and should use, but not engineers, and thus the Engineer was puzzled and saddened. The new young men who dared to call themselves electrical engineers apparently knew how to use this kind of mathematics, and, what was worse, they would impudently apply it to other fields of engineering, and come up with answers to problems that *really* had no *practical* importance, but seem to be theoretically interesting.

Everybody knows that an infection spreads easily: the mathematical infection became an epidemic. It invaded hydraulics and structures, and even the field of machinery and of heat, so that even the Engineer found himself surrounded by formulas and was compelled to read papers in which the results of research, of course, *purely theoretical* research were presented in mathematical form. It is true that mathematics had been used before in *practical* problems, like those concerned with the accurate launching of a piece of steel that would kill as many enemies as possible, but this was the field of the military engineer, not the Civil Engineer. By the end of the 19th century the "new approach" had spread to all fields of engineering, and in some schools one saw physicists and mathematicians take over the teaching of engineering subjects! In less than 30 years a revolution had taken place. Physical intuition and practical problems had abandoned the halls of the schools of engineering, apprenticeship was at an end, and engineering had become a science. The Engineer felt lost.

In the next 30 years the scientific trend in engineering reached such heights that engineers suppla-

nted physicists in all but nuclear research, and one heard the rumblings of nuclear engineering research going up the ladders of physics to penetrate the inner sanctum of science itself. The physicists did not mind, since they had such fascinating problems to solve inside the nucleus that slightly larger size realms were considered unworthy of their attention. Even the mathematical physicist gave up his job and allowed it to be taken over by a new engineer called an applied mechanician. The amazing thing was that both science and engineering thrived under these conditions, and that neither the public nor the poets seem to resent this state of affairs, except, perhaps, for the few who did not like the thought of going on a vacation to the moon in order to get away from the fall-out of the cities.

But at the lower levels of engineering the situation was not as rosy as it looked on the surface. Granted that rockets were regularly mailed to the Moon and to Venus, that no player could play a championship game without been seen by 3 out of 6 billion people on earth, that it was convenient to rest on the Island of Capri during lunch time while working in Alaska (underground, of course), but a few "basic items" began getting hard to find. For example, if anyone asked for a house to just live in, with windows and doors and a backyard, he would find that there were almost none on the market. And if he inquired about this difficulty he would be told that houses were usually designed by civil engineers and that civil engineers were a breed of the past. The state schools and even the Ivy League colleges only produced electrical engineers or applied mechanicians, so that the field of so-called civil engineering was empty of practitioners. Who would want to study sewage or railroads when he could work on vibrations of crystals (so much cleaner!) or wave propagation (so much faster!). Who could want to worry about bridges when one could design a supersonic shuttle to connect the two banks of a river by bouncing it off a satellite? Of course, a few houses could still be bought, entirely assembled in a factory and delivered by helicopter to the site. But sites were getting rarer and rarer, and most people preferred to live in underground shelters (so much safer) under perfectly controlled conditions of temperature, pressure, humidity and psychic tension (which became relaxation during the 4 day week-end). The truth of the matter is that the Engineer was not needed any more and thus he slowly vanished, like all unnecessary species. It is true that not all of his activities had become obsolete. For example, a few calculations had to be performed in the design of the few structures still built, but these were carried out on computers, who could be programmed to do anything the old Civil Engineer did, and to do it better and faster. A molecular computer could be bought for a few cents, and there were so many specialized types that even the flourishing industry of printing manuals dwindled. It did not pay to produce solutions and store them in books: it was much cheaper to create the solutions anew everytime one was needed, and thus introduce the smallest variations in the conditions under consideration. One got at the same time, accuracy and economy, and the so-called "handbook engineer" could now proudly call himself the "computer engineer". Some die-hards insisted for a while in using Engineers in the direction of construction and in the organization of manufacturing, but these were soon dropped from their jobs, since a computer could not only do as well as they did, but could optimalize production on a world basis, and at the same time manage the totally automized factories.

The dynosours had taken a long time to grow and then to give up the earth to their successors, who in their turn lost their lead and vanished in order to produce man. Man had taken a long time in inventing rational thought and, finally, in creating as the perfect end-product of his own revolutionary process, the Civil Engineer. But the engineers took no time at all in evolving science, and the scientific engineer disposed of the Civil Engineer in a matter of half a generation. A few mummified specimen of this species were exhibited in museums of anthropology and little children were allowed to see how their brains worked. But it was such a simple process that children enjoyed the game for a while and then got bored, since they could immediately suggest tremendous improvements and were frustrated when they realized that the Civil Engineer could not be changed and should be left intact in order not to lose his historical value.

Thus the glorious era of Civil Engineer was a short period in the evolution of mankind. And nobody cries over the disappearance of this tenuous link between the dark ages of the 19 hundreds and the truly scientific times we are privileged to live in.

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Grant Bloodgood
Chief Engineer
Bureau of Reclamation

Importance of Research in Bureau of Reclamation Water Resource Development

ENGINEERING RESEARCH HAS CONTRIBUTED IMMEASURABLY to the Bureau of Reclamation's objective of planning, designing, and building water conservation projects in the 17 Western States of the United States. Research in all phases of Reclamation water resource development—from planning, investigations, design, and construction, through operation and maintenance—has been essential in achieving safety, economy, and competency in engineering accomplishment.

A basic principle since establishment of Reclamation in 1902 is that money expended in carrying out western project development must be substantially repaid by those for whose benefit it has been spent. The Bureau thus has the particular responsibility to construct water resource facilities economically and within the ability of the beneficiaries of such works to repay the costs of construction. Research provides constant stimulus and direction in carrying out this responsibility. In the past 10 years alone, Reclamation research in concrete, hydraulics, soil mechanics, and other engineering fields has resulted in estimated savings to Bureau projects of more than 60 million dollars.

The most significant economies through research cannot be evaluated in monetary terms. A new material developed through research, a new method of using conventional materials, or a new concept permitting more economical design may result from studies on a single project. The economies thereby accomplished on the one project will be duplicated on every similar project to be built by the Bureau in the future. Other Government agencies and private construction agencies will likewise profit from the new development.

Reclamation projects store, control, and convey water for irrigation of previously unproductive lands, thus reclaiming the lands for productive agricultural purposes. Many of the projects are multiple purpose in scope, and they function for maximum utilization of scant water resources in large areas or entire river basins. These projects conserve, control, and utilize water for irrigation and for generation of hydroelectric power, flood control, municipal water-supply, recreation, fish and wildlife preservation, and other beneficial functions.

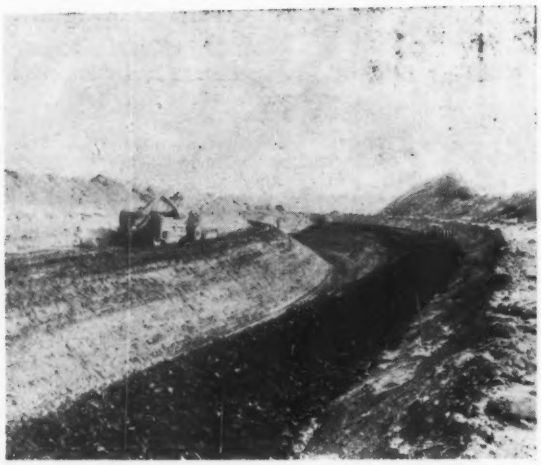
The 79 Bureau of Reclamation irrigation projects serve more than 128,000 farms and embrace a total of 8,049,000 acres. A total of 6,756,000 acres was irrigated during 1958, producing crops valued at more than $987,000,000. The more than 5 million kilowatts of hydroelectric power now available from Reclamation powerplants meet community, industrial, and agricultural needs.

The co-ordinated endeavour of laboratory tests and investigations and field observations and surveys has contributed substantially to these accomplishments. Laboratory research is essential to the determination of the properties and the best techniques for the use of construction materials, in predicting structural behaviour, in appraising adequacy of structures, and in determining operating characteristics of hydraulic facilities. Field research extends the knowedge of operating behaviour of structures and leads to improved and more economical operation of completed works.

Laboratory Research

Laboratory research is centered in the Bureau's engineering laboratories at Denver, Colorado. The laboratories have made major contributions in virtually every phase of water resource engineering. In the fields of hydraulic research, in structural testing, and in investigations of construction materials, laboratory effort has increased the flexibility of design and construction methods. Extensive laboratory research has developed new approaches to engineering problems and has been instrumental in achieving major economies in the design office and in the field. The engineering laboratories today serve as indispensable aids in the planning, designing, building, and operation of Reclamation works.

Hydraulic research has embraced a widely diversified scope of specialized problems not amenable to



Construction of the thick, compacted earth canal lining developed by the Bureau of Reclamation.

analytical solution. Working models of hydraulic structures such as dams, spillways, canal chutes and drops, outlet works, stilling basins, conduits presenting special problems, and hydraulic machinery and appurtenances have been studied in model form for adequacy of performance and for determination of forces acting on them and their prototypes. Such model tests have led the way to great improvements in hydraulic operating characteristics, safety in operation, and economies of design. The solution of specific problems has also yielded a wide range of hydraulic data and experience of value in the solution of future problems.

Hydraulic research techniques have enabled correction in designs which would have produced cavitation necessitating costly repairs to structures and machinery. Similar techniques have been employed to advantage to increase the coefficient of discharge of hydraulic structures. Reduction in the size of water passages has made economies possible in many structures when laboratory studies pointed out practical design modifications. Dimensions of spillway chutes have been decreased in many instances and the operation of these features has been improved..

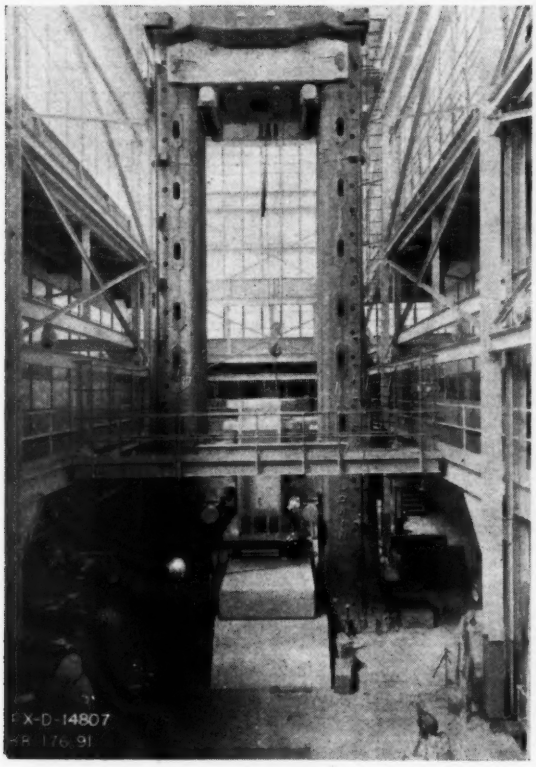
The hydraulic laboratory has extended its usefulness by the application of electronic analogs and membrane analogies to the study of certain hydraulic phenomena. Such application has been valuable in salinity studies and in sedimentation investigations.

A primary requisite to sound design and construction has been the structural research conducted for the accurate measurement of stress, strain, deflection, and other physical defects developed in structures in use. Tests on models of girders, columns, frames, gates, and other structures or structural parts have been invaluable adjuncts to safe and economical designs. This research has also been applied profitably to the study of foundations and characteristics of materials, particularly stress-strain relations. A variety of special equipment, including the 5,000,000-pound capacity universal testing machine, the triaxial testing machine, and special optical, mechanical and electrical measuring devices in the laboratories have been employed in numerous structural studies.

The development of tests to determine the suitability of natural construction materials, the intensive inquiry into the properties of portland cement, the procedures developed for evalutaing and designing optimum concrete mixes, and the introduction of new construction materials into Reclamation activities, exemplify the contributions of materials research. In concrete technology noteworthy progress was made in determination of alkali-aggregate reactivity, in uses of pozzolanic materials, and in introduction of air entrainment in concrete mixes. Laboratory research on concrete materials has contributed to the development of five distinct types of portland cement each having properties most suitable for particular purposes. From such researches have come also basic criteria for control of mixing, transporting, and placing of concrete, and for the proportioning of materials in concrete for adequate quality and workability. Noteworthy progress has also been made in the analyses of thermal properties of concrete, in the measurement of volume change, and in the studies of durability, permeability, strength, elasticity, and other properties of concrete. Major economies resulting from such research have been demonstrated.

Use of pozzolan in the mass concrete for the 4,865,000-cubic-yard Glen Canyon Dam will reduce the amount of cement otherwise required, bringing about a savings of about $1,300,000. Another savings has been brought about through adaptation of a technique known as heavy-media separation, which

Hydraulic model tests predict the behavior of prototype structures and allow the study of new designs without excessive cost.



The 5,000,000-pound capacity Universal testing machine, largest of its type in use in the world today, is an important tool of Reclamation's laboratories engineers. Delicate electronic instruments record the stresses and strains in materials as they are subjected to the forces applied by the testing machine.

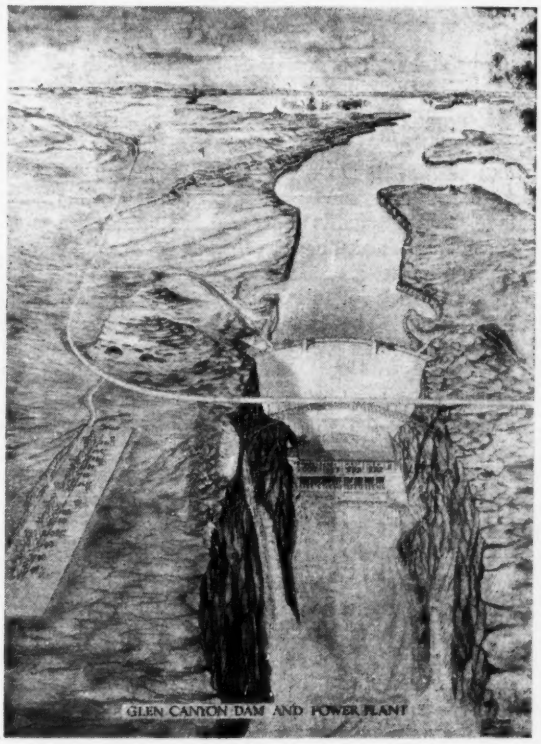
makes it possible to utilize part of otherwise unsuitable aggregates in the mass concrete; thus savings of approximately $6,600,000 will be realized in the construction of the dam. The heavy-media separation will also make possible a savings of $2,000,000 in the construction of Flaming Gorge Dam, a major water and power storage dam being built on the Green River in the State of Utah. To this large savings, Reclamation engineers are adding a savings of $500,000 by specifying the use of pozzolan in the concrete for Flaming Gorge Dam.

To meet greatly expanded needs for data on earth materials, laboratory research has undertaken basic studies of special soils problems. Procedures have been developed for chemical and microscopic examinations of soils. Utilization of soil tests and improved knowledge of foundation conditions through laboratory-developed techniques have been important factors in the development of earth dam design and construction.

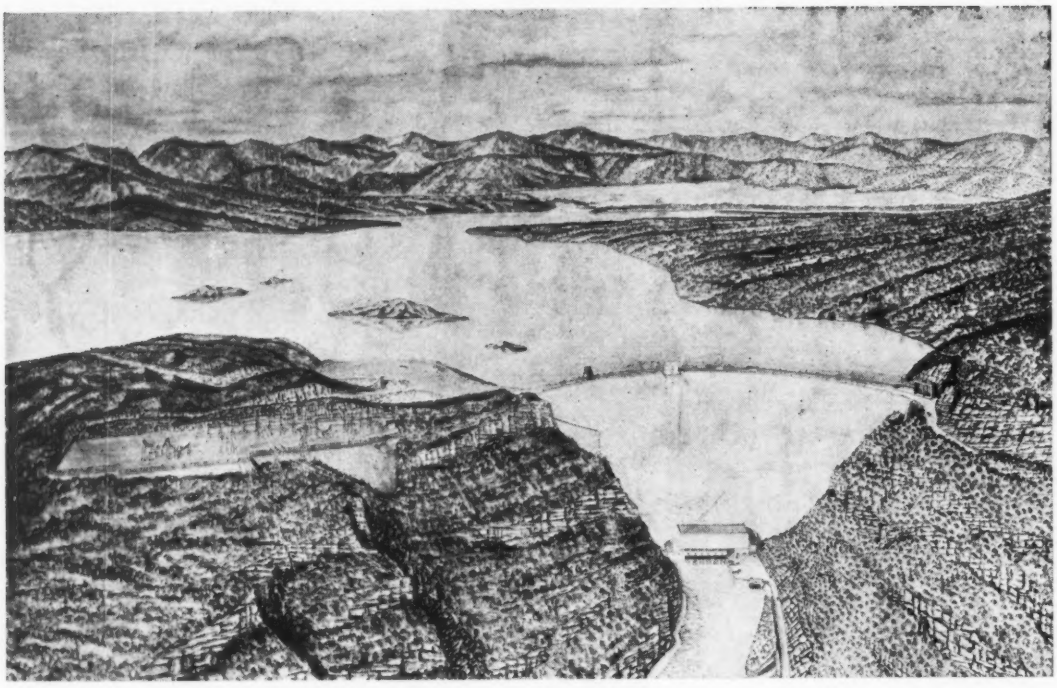
The introduction of relatively inexpensive heavy type compacted earth linings for canals received its major impetus through earth laboratory investigations, as did the jetting and vibrating method of compacting cohesionless soils for backfill. Better exploration and testing techniques developed in the laboratory are leading to more economical foundation designs for a variety of structures.

Tests for determining the effect of varying amounts of gravel particles on compaction, permeability, consolidation, and shear properties of soils are underway in the earth laboratory. A large compaction machine was developed in the laboratory to study the compaction characteristics of gravelly soils. The compaction properties of soils containing particles up to 3 inches in size can be determined with this apparants.

Research work is being conducted with the laboratory's large-scale triaxial shear apparatus to study the shearing characteristics of soils containing particles up to 2 inches in size. Large-scale permeability and consolidation tests are also being made on soils containing large particles. This type of research is of particular value in the design and construction of large earth dams, earth canal linings, and earth canal embankments, where stability and water barrier characteristics are of great importance. Electrochemical methods of reclaiming soils and stabilizing embankments are also being investigated. A laboratory-developed radioisotope sediment densitometer is being



Artist's conception of Glen Canyon Dam and Powerplant.



Artist's conception of Flaming Gorge Dam and Powerplant.

used to measure under water the density of sediment in reservoirs.

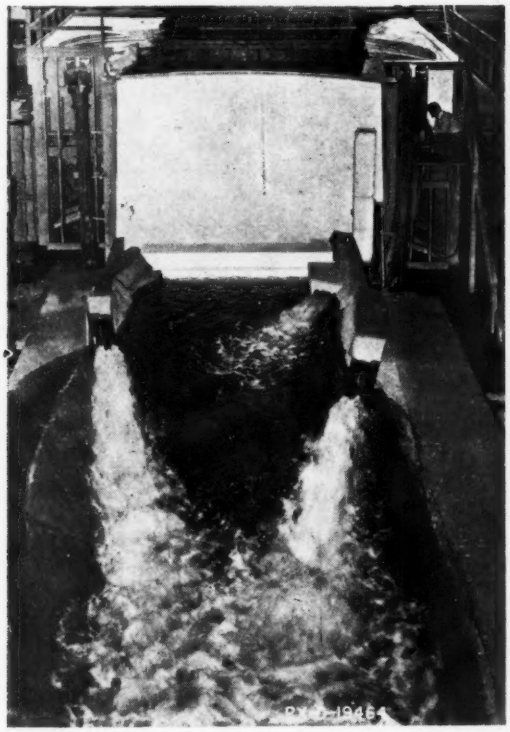
Laboratory tests were conducted to determine the suitability of a soil-cement mixture for the upstream face of Merritt Dam, an earthfill structure proposed for construction on the Missouri River Basin Project in Nebraska. This is the first large earth dam to be considered for facing with a soil-cement mixture. Soil-cement is proposed for the dam as a substitute for riprap, as rock suitable for riprap is not available near the damsite. The laboratory investigations of soil-cement mixtures include compressive strength tests and the ability of the mixtures to withstand freeze thaw, wet-dry cycles. The soils available near the dam site for the soil-cement facing contain varying amounts of volcanic glass and the effect of this material on soil-cement was studied. Other factors such as the use of an air entraining agent in soil-cement, and the use of retarders for delaying cement set to facilitate construction were also investigated.

Research engineers have contributed to the knowledge and application of other materials, including paints and oils, bituminous materials, and metals. Bentonites and other clay minerals have been studied for their usefulness for certain construction applications. Tests designed to evaluate protective coatings and their ability to prevent corrosion have been valuable aids to the uses of new materials and have lengthened the serviceability of standard materials.

Bureau laboratory investigations of representative specimens from approximately 60 samples of assorted plastic products submitted by some 15 manufacturers during the past 10 years for testing as possible materials adaptable to low-cost prefabricated canal linings, indicated that the more common polyethylene and vinyl plastic films of 8 thousands of an inch minimum thickness are potentially satisfactory materials for buried membrane canal linings. Tests on the plastics, some of which have been in soil burial environment for the full 10 years, indicated that many of the plastic films are watertight, tough, resistant to biological and chemical deterioration, and impenetrable by growth of most weeds. Plastic films incorporating organic material, such as canvas or burlap, were found to be less resistant to biological deterioration than the unreinforced plastic films.

Through its weed control research program the Bureau has made rapid strides in the investigation of the effectiveness and economy of weed killers. Studies of growth habits of weeds and their control have been important. Aromatic solvents such as low cost coal-tar naphtha with an emulsifying agent have been developed to control aquatic weeds. Recent laboratory research has utilized radioactive isotopes to study plant physiology and the effect of herbicides on aquatic and land-type weeds.

Results of a laboratory study to determine the effects of shading from sunlight on the growth of



Scale hydraulic model of Glen Canyon Dam, showing the twin spillways, outlet works and powerplant discharging maximum flows. Total river discharge is about 300,000 cubic feet per second. Spillway approach areas are visible at top of the photograph.

pondweeds, produced by suspended sediment, indicated low concentrations (50 to 100 parts per million) of suspended sediment create sufficient shading to produce significant growth reductions of submersed aquatic plants. The study evaluated growth response of various species of submersed pondweeds exposed to an environment consisting of 6 concentrations (50 to 5,000 parts per million by weight) of two types of suspended sediments. Intensity and spectral quality of solar radiant energy, penetrating the sediment-laden water, were measured during the course of the study.

The use of aromatic solvents in the 17 western states has resulted in a total estimated savings of $6,200,000 since development about 11 years ago. At present, the estimated annual savings is about $1,160,000. Weed control research promises additional savings. Studies now in progress indicate that even more efficient and economical chemicals for control of weeds in canals can be developed and utilized.

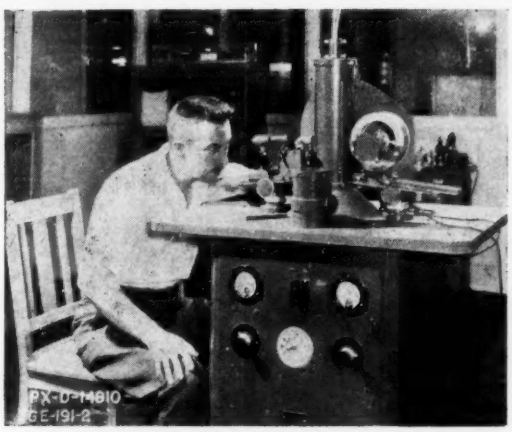
Field Research

Research is of great importance in the field where new developments can be introduced and observed under actual operating conditions. A variety of field programs has been carried out as joint endeavor by the Bureau's project offices and the Denver engineering office. This cooperative effort has been successfully applied to improvement of structure performance and to the furtherance of new economies in design, construction, and operation.

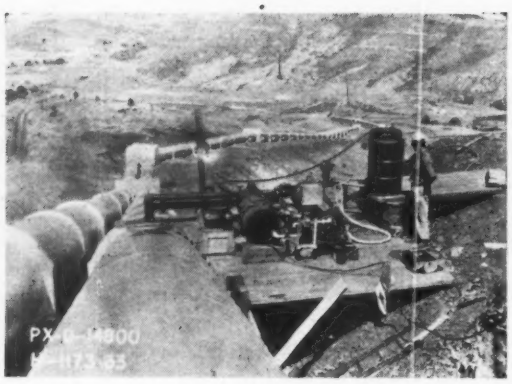
Such coordinated research is typified by the development of lower cost canal and lateral linings. Prefabricated asphalt, buried asphaltic membrane, and heavy type compacted earth linings, among others, have been successfully introduced, following intensive laboratory investigation and field study. Marked improvement in construction techniques and reduction of costs of canal linings have resulted from field and office analyses of operations and subsequent recommendations.

The control of reservoir evaporation is under intensive study in the field and in the laboratory. A monomolecular layer of certain organic compounds—a floating invisible shield between air and water—has been demonstrated to have considerable potential usefulness in reducing evaporation from open reservoirs. In the summer of 1958, detailed evaporation reduction investigations utilizing the alcohol, hexadecanol, for forming the monomolecular layer, were undertaken at the 2,500-acre Lake Hefner, a municipal water supply reservoir for Oklahoma City, Oklahoma.

During the period of the treatments at Lake Hefner, it was possible to achieve an overall reduction in evaporation of slightly more than 9 percent, although weather conditions were not favourable for maintaining the film. It was reported that this is about one-fourth of the potential reduction with the kind of material used at Lake Hefner at the water temperature experienced. The water savings by evaporation reduc-



X-ray diffraction is a nondestructive means of determining qualitatively and quantitatively the composition of small samples of material. Here an engineer is mounting a sample of cement for analysis in the apparatus.



Field testing includes verification of the design and laboratory studies of the completed structure. Hydraulic data are also derived for application to future design problems. Illustrated here is an installation for measuring the rate of flow in a penstock.

tion at Lake Hefner were accomplished at a total cost for labor and hexadecanol approximately equal to the total value of the untreated water saved for Oklahoma City. No hexadecanol or any materials derived from it could be detected by the United States Public Health Service in water reaching the inlet of the Oklahoma City water supply. Oklahoma City officials found that concentrations of micro-organisms normally present in lake waters increased markedly as a result of feeding on the hexadecanol. However, the purified water met Public Health drinking water standards. Under an operational program with improved procedures and materials, the costs of evaporation reduction would be expected to be considerably less than experienced in the Lake Hefner trial. Further reservoir evaporation reduction investigations were undertaken at a reservoir in Arizona in the summer of 1960.

The Bureau of Reclamation, in cooperation with the Soil Conservation Service and the Agricultural Research Service, is engaged in a field study of developing procedures for evaluating the effects of watershed practices upon water yield. The program, termed the Cooperative Water Yield Procedures Study, is a 5-year undertaking begun in May of 1957 to study and evaluate such watershed practices as terracing, land treatment, strip cropping, contour farming, and stock ponds. At the end of 2 years of the study, considerable information was gained on the relationship of watershed treatment to rainfall runoff of streams. The information obtained and the analyses made are to be of considerable value in future studies of the effects of watershed practices upon streamflow.

Cooperative field studies of the water consumption by salt cedar conducted by the Bureau of Reclamation and the U.S. Geological Survey are underway at a 10-acre site in Arizona. The studies are expected to be significant not only in the control of the objectionable phreatophyte plants, but also in the development of techniques to study the water consumption of beneficial crops raised on irrigated projects.

The water use studies are being made through the use of six lysimeters, 33-foot square by 10-foot deep tanks which are placed in the ground and in which salt cedar plants were transplanted for observation of growth with water levels maintained at different depths. Instruments to measure accurately both water budget and energy budget for water table conditions were installed.

Field examinations and tests were recently made of plastic and synthetic rubber-coated nylon fabric (neoprene) canal lining material, in service for about 5½ years on a canal of the Huntley Project in Montana. The tests indicated that both materials were in very good condition and did not undergo any significant chemical or physical changes. The total length of the several reaches of the canal lined was 491 linear feet for an area of approximately 1,200 square yards. The plastic lining varied in thickness from 3 thousandths to 20 thousandths of an inch. The neoprene lining was 9 thousandths of an inch thick. The plastic materials were installed both as buried and exposed linings; the neoprene material was installed as a buried membrane. In 2 years or less, the uncovered plastic linings failed completely, owing to exposure to the weather and erosion. Periodic inspections made of the buried membranes indicated that even the 3 thousandths of an inch thick materials (recommended thickness is 8 thousandths of an inch) were in good condition, performing satisfactorily. The covered materials tested were placed in the bottom and side slopes, both below and above the waterline. The cover material varied in depth from 1 inch to 18 inches.

A variety of coating materials for steel pipe that have shown promise in laboratory tests are being evaluated under service conditions on the Collbran Project in Colorado. Thirty-six experimental coatings were applied in the summer of 1959 to a 280-linear foot section of the 72-inch steel siphon of the project's Southside Canal. The pipe, in 40 foot sections, was lined in the fabrication plant. Twelve manufacturers supplied materials for the test and sent representatives to participate in their application. Several synthetic resin-based paints, sprayed aluminium and zinc with and without topcoats, neoprene, chlorinated rubber, asphalt enamel, and other coatings were included for comparison with presently specified Bureau protective coatings, such as vinyls, phenolic red lead, and the coal-tar enamel which protects the remainder of the siphon piping. The experimental coatings will be inspected at intervals during service to ascertain their relative performance.

Seepage experiments using the radioactive hydrogen isotope tritium as a tracer were carried out in the fall of 1959 on the Madera Canal of the Central Valley Project in California. The experimental work was

under contract with the Bureau as part of its Lower-cost Canal Lining Program. A 500-foot reach of the canal was studied. Test wells drilled in the bank of the canal and in adjacent areas along the assumed path of the seepage water were used to trace the passage of the tritium which revealed the direction and amount of water that seeped from the earth-lined reach of the canal.

Full-scale field trials of the geophysical technique of electrical logging to detect possible leakage from operating canals have been carried out on the Central Valley Project. Electrical logging permits a continuous measurement and recording on a chart of variations of the electrical resistance of materials making up the bottom and/or banks of a canal. Logging has shown that water lowers the resistance of earth materials, and in those reaches of a canal where the resistance is low, leakage may be suspected. Identifying such reaches permits subsequent verification of the leakage and remedial measures as necessary. During the trials of a total of more than 7 miles was logged in selected reaches of four major project canals.

Drainage of irrigable lands has been under concerted study in the field, particularly in recent years. Improvement of techniques of analyzing the physics and chemistry of soils has made possible great strides in drainage practices and appraisal of drainage possibilities. Reclaiming of numerous areas on which alkaline and saline conditions prevail and adoption of measures to prevent alkalinity and salinity in soils have followed from drainage investigations.

The first of a series of tests on a new technique of applying copper to algai-infested water conveyance channels was recently completed by Reclamation weed control scientists. Copper is an effective algaecide as well as a deterrent to submerged weed growth. The equipment used in the test, installed at a seepage ditch on the Colorado-Big Thompson Project in Colorado, consisted of a rectifier and a specially designed coil of 2 large copper wires through which a direct current was applied. As the current was applied minute quantities of copper were dissolved into the water of the ditch, inhibiting the heavy growth of filamentous green algae present.

For concrete dams, observations of internal stress conditions through instruments embedded in the structures have made possible the development of new criteria for design. Similarly, measurements of pore pressure, internal stresses, and consolidation recorded by instruments installed in earth dams have served as continued checks on structure behaviour and have led to major economies and improved practices in design and construction.

A new device, developed by Bureau engineers to measure horizontal deflections, was installed in the earth embankment of Trinity Dam, now under construction on the Central Valley Project, California. The apparatus is providing information on the horizontal and vertical movements within the 537-foot high structure and is adding to the knowledge of the stress-strain properties of soil to aid in future designs of high rolled earthfill dams.

A co-operative program, undertaken jointly by Reclamation and the Coast and Geodetic Survey, has provided information relating to occurrence of earthquakes. Seismograph stations installed in various areas of the west record seismic disturbances. Data thus obtained are invaluable aids to the designing and building of safe and economical dams and other structures.

Future Research

Experience has shown that the more that is learned in a particular field of research, the more opportunities appear for future extension of knowledge and future benefits. Rewarding returns can be seen at this time from continuation of virtually all the principal research projects in engineering methods and materials that pertain to Reclamation activity.

There is a possibility that an expanding type of cement can be developed to nullify the inherent shrinkage in concrete caused by drying. Possibly an admixture can be found that will introduce greater flexibility in concrete without sacrificing too much in strength and durability. Better resistance of concrete to erosion, cavitation, and chemicals is needed, and the whole field of more efficient construction methods of concrete should be explored. Because there are many unanswered questions concerning the behaviour of plain and reinforced concrete, and because new structural uses of concrete are constantly being developed, there is a vast need for research in the field of structural concrete.

Although there are preferred types of soils for a particular structure, the engineer must make the best of the soils that are available at the site. New research is needed in analyzing soil reaction to loads, evaluating soils properties to take full advantage of them in design, devising satisfactory uses of materials available at the site, although their quality may be at a minimum, and devising ways of changing or improving questionable soils to meet the requirements of the structure. Soil pressures, which are now analyzed by theory and liberal assumptions, have not been measured with certainty. Although present methods have been useful, there is much need for improvement in instrumentation to evaluate accurately soil pressures in earth structures so as to use the properties obtained by controlled laboratory tests for efficient and competent designs.

Despite the many investigations made in laboratories throughout the world, hydraulics is still an inexact science. This is because of the almost infinite number of geometric patterns through which flow can pass in a hydraulic system, and because the

World's highest earthfill dam, Trinity Dam, under construction. When completed the dam will be 537 feet high.

combinations of the other variables which affect hydraulic flow, such as velocity, depth, boundary roughness, and others, are almost endless in number. Although many basic problems have been solved to some degree, more research is needed to provide more exact data and thereby eliminate the need for exceptional judgment and experience in the engineers who design hydraulic structures. For example, it is not possible to predict accurately the behaviour of large quantities of water flowing at high velocities through hydraulic structures. It is not possible to design economically proposed spillways and outlet works with confidence, unless they are very similar to those which have been shown to perform satisfactorily in the past.

Part of these difficulties stem from the fact that better testing techniques and equipment are needed. Research is needed to provide instrumentation for measuring instantaneous pressures and velocities in turbulent flow. This would permit obtaining more fundamental information on some of the basic and common flow phenomena, such as the hydraulic jump, and the pitting resulting from cavitation. Despite the fact that hydraulic structures have been built for many years, damaging vibrations still occur in gates, walls, and other hydraulic structures. The erosion of riverbeds resulting from turbulence and eddy currents is another ever-present problem. Additional investigations and measurements must be done in the field to assure that future large canals can be depended upon to perform as intended. Currents introduced by difference in water density due to salinity, temperature, or sediment should be studied to permit more accurate design of river structures, such as salt water barrriers, reservoir outlets, and inlets to canals.

Before the full potentialities of the use of monomolecular layers for reservoir evaporation reduction can be realized, considerable work is needed in the development of practical methods of applying and maintaining the film on the water surface. Such studies require laboratory investigations of the possible chemical and physical forms of the film-producing chemical. The design and development of suitable equipment and techniques for using the various forms of the chemical would require much additional information on the effects of meteorlogical and hydrological factors on the behaviour of the film.

Little is known of the dynamic factors of water-column separation in pump discharge lines. Certain designs may function satisfactorily in the presence of water-column separation, but others may require special equipment to eliminate the effects of the sepa-

ration which might cause pipeline failure. The extension of field testing on existing and proposed systems is needed to measure these factors so that adequate and economic designs can be made.

In view of the great interest in corrosion today, it is surprising how little is known as to why iron and steel corrode rapidly in one water or soil and not in another. The design of cathodic protection systems is still largely a matter of trial, particularly for complex structures. Although protective coatings have been greatly improved in recent years, the maintenance of submerged and buried metalwork on irrigation projects is still a major operating expense. Possibly entirely new types of coatings can be developed. Research has shown that very small amounts of impurities have pronounced effect on the properties of a metal such as iron. Research may lead to the development of a comparatively cheap metal which is highly resistant to corrosion. The entire field of corrosion and methods of control is worthy of much research.

Much additional research is needed to establish more efficient and economical chemicals for aquatic weed control, and fundamental research is required to determine the mode of action of the toxicity of acquatic herbicides. Such work will require the use of the most modern and up-to-date research methods, such as use of radioisotopes. The study of new chemicals should be accompanied by continuing research in improved methods of culturing and growing plants for test purposes. The most effective use of any technique of weed control can be developed only after an increased understanding of the physiology and ecology of aquatic weeds. Considerable field and laboratory study is needed. There is a need for practical methods of controlling weeds in large canals. The solution of this problem will require the performance of extensive field work, co-ordinated with intensive laboratory research.

The full utilization of radioactive materials requires much additional research. Additional research in the use of tracer techniques could provide accurate answers to many important questions in weed control, water velocity measurements, sediment bed-load measurements, seepage, ground-water movement, and many types of chemical analysis. Considerable research must be done before the use of gamma rays for sediment and soil density measurement is fully developed. Similarly, soil moisture measurement using neutron radiation can be more highly developed, and this technique should be studied for possible use in measurement of moisture in portland cement concrete and asphaltic concrete.

Summary

Research in the laboratory and in the field has been a productive and important factor in the Bureau of Reclamation's water resource development program. Research has not only given impetus to development of new engineering applications, introduction of new materials, and to amplification and strengthening of existing procedures, but it has also been responsible for major economies in design and construction.

The benefits resulting from Reclamation research are not restricted to Bureau projects. The research problems investigated by the Bureau are common to all concerned with engineering in water resources development, and to a large extent in other engineering fields. The cost of research is repaid many times over on Bureau projects alone, and it is equally valuable to the nation and to the world.

Research will continue to have profound influence on the Bureau of Reclamation activities for the future. The design and construction of dams of great heights under difficult foundation conditions and the conveyance and distribution of water in larger quantities over increasingly greater distances through research. Other challenging problems include the extension of project developments through transbasin diversions of river waters, the development of more effective and economical means of silt control, the improvement and optimum use of knowledge of underground water storage, and the transmission of electrical power to meet expanding needs. These problems will be met through the initiative of research, coupled with sound engineering judgment.

RIVER VALLEY DEVELOPMENT is one of the major programmes of development in Asia today. The discussion of problems connected with it—technical, economic, social and organisational—is most vital. This Journal has done its little bit in the last ten years. As the only journal of its kind in this region, it will continue to perform this important function.

A. M. Komora
Formerly Chief Engineer
Damodar Valley Corporation

Some Thoughts on DVC—Ten Years After

In its early days the Damodar Valley Corporation was referred to as the TVA of India and that it was patterned after the Tennessee Valley Authority. This no longer need be the case. The DVC has grown up and can stand on its own feet. Twelve years ago the DVC was a dream, a dream which has now become a reality. It was founded as a Corporation for the unified development of the Damodar Valley. The results speak for themselves as to how well the original objectives have been attained.

Criticisms, both just and unjust were levelled against the DVC. The unjust criticisms were made by people who did not have all of the facts at hand or who were probably misinformed. Gradually, with the passage of time, the criticisms abated in volume and in intensity. This was probably due to two reasons. Firstly, as the various projects came into being tangible results started to accrue to the people. The public, at large, could actually see definite accomplishments. Secondly, a concerted effort was made to inform the public as to the facts and accomplishments of the DVC. The Indian Journal of Power & River Valley Development helped, in a large measure in this effort, through its publication of technical papers and editorials.

The DVC started out in 1948, literally, from scratch. There was no ready pool to draw from of experienced engineers and trained technicians. That some mistakes were made cannot be denied but such mistakes as were made (and there were very few considering the magnitude of the project) were those that any sincere and honest people will make in carrying out their assigned duties. The only person who does not make any mistake is the one who does no work. In this respect the "just" criticisms were welcome and due consideration was given to them.

With the passage of time, starting with Tilaiya and Konar in 1950 and ending with Panchet Hill and Durgapur Thermal Station in 1959, the quality of workmanship and the speed of construction increased tremendously. This was quite a natural outgrowth. The construction forces, from the top engineer to the lowest mistri, gained experience and with this experience came confidence in their ability to carry out their respective tasks. These same men, working as a team, could complete a similar project in less time and at less cost than they did the previous projects.

Credit for completing the DVC successfully should be given to the following agencies:

1. The DVC Management acting through its Chairman, Board Members and Administrative Staff, who devoted their full time, individually and collectively.
2. The International Bank for Reconstruction and Development which granted three separate loans for much needed foreign exchange with which to purchase major permanent and construction equipment. To the various members of the World Bank who gave timely and much needed advice.
3. The Technical Cooperative Mission which made possible the employment of a consulting engineering firm and certain qualified technicians
4. The Harza Engineering Company who made the major part of the designs for the Maithon and Panchet Hill Projects. The various Resident Engineers of this Company who supervised engineering and helped to train up Indian design engineers.
5. The Gruner Brothers, Consulting Engineers who made the plans for Konar Dam and who supervised construction of this project.
6. The Kuljian Corporation who engineered and supervised the construction of the Bokaro and Durgapur Thermal power stations.
7. The Hind-Patel Company who constructed the Konar Project.
8. The Hindustan Construction Company who constructed various bridges and the civil works for the Maithon powerhouse, the first underground power station in India.
9. The DVC Board of Consultants, Messrs. S. O. Harper, the late L. F. Harza, A. J. Ackerman, Kanwar Sain, T. Iyengar and A. Venkatachari who gave much needed and wise counsel.

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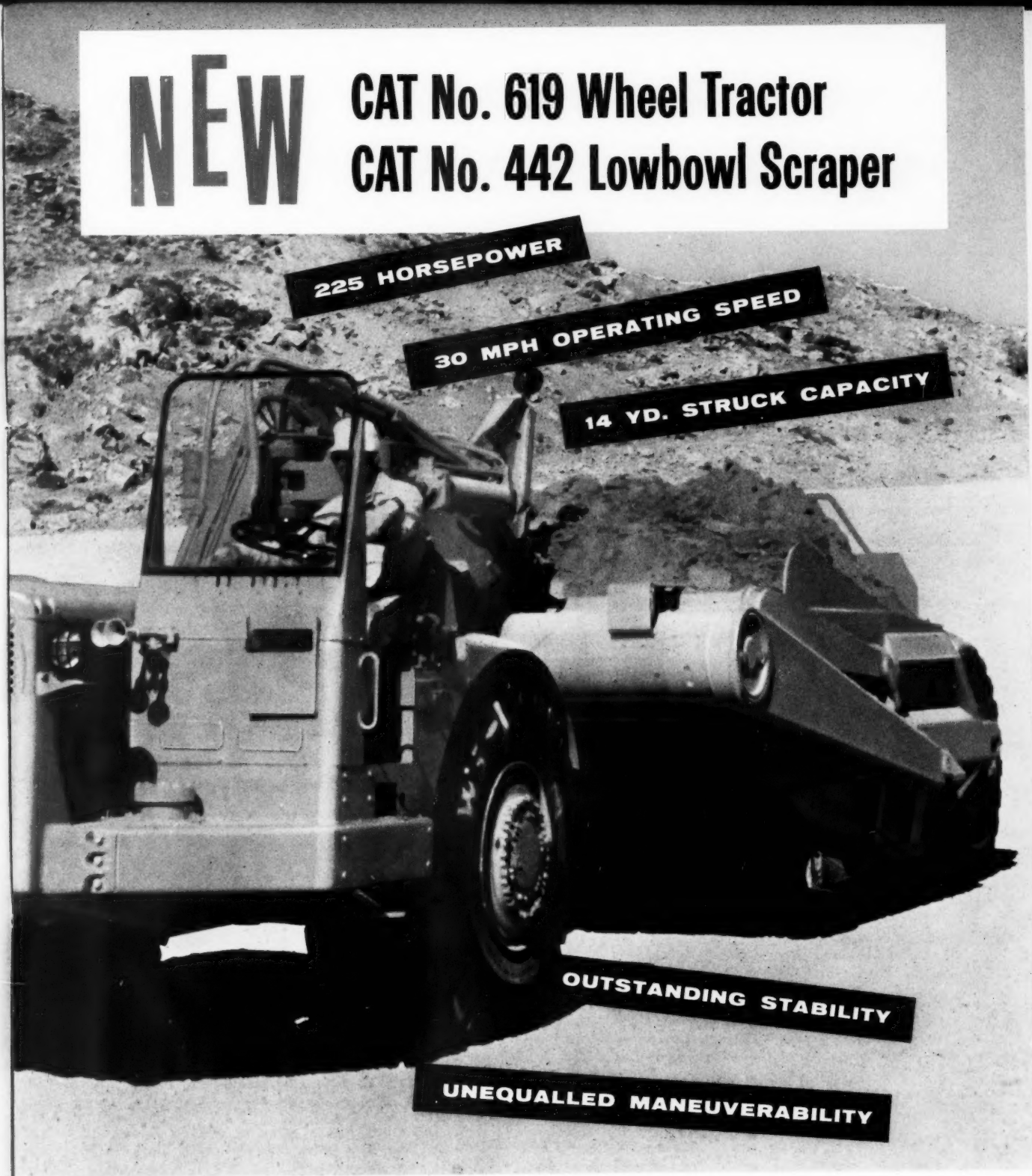

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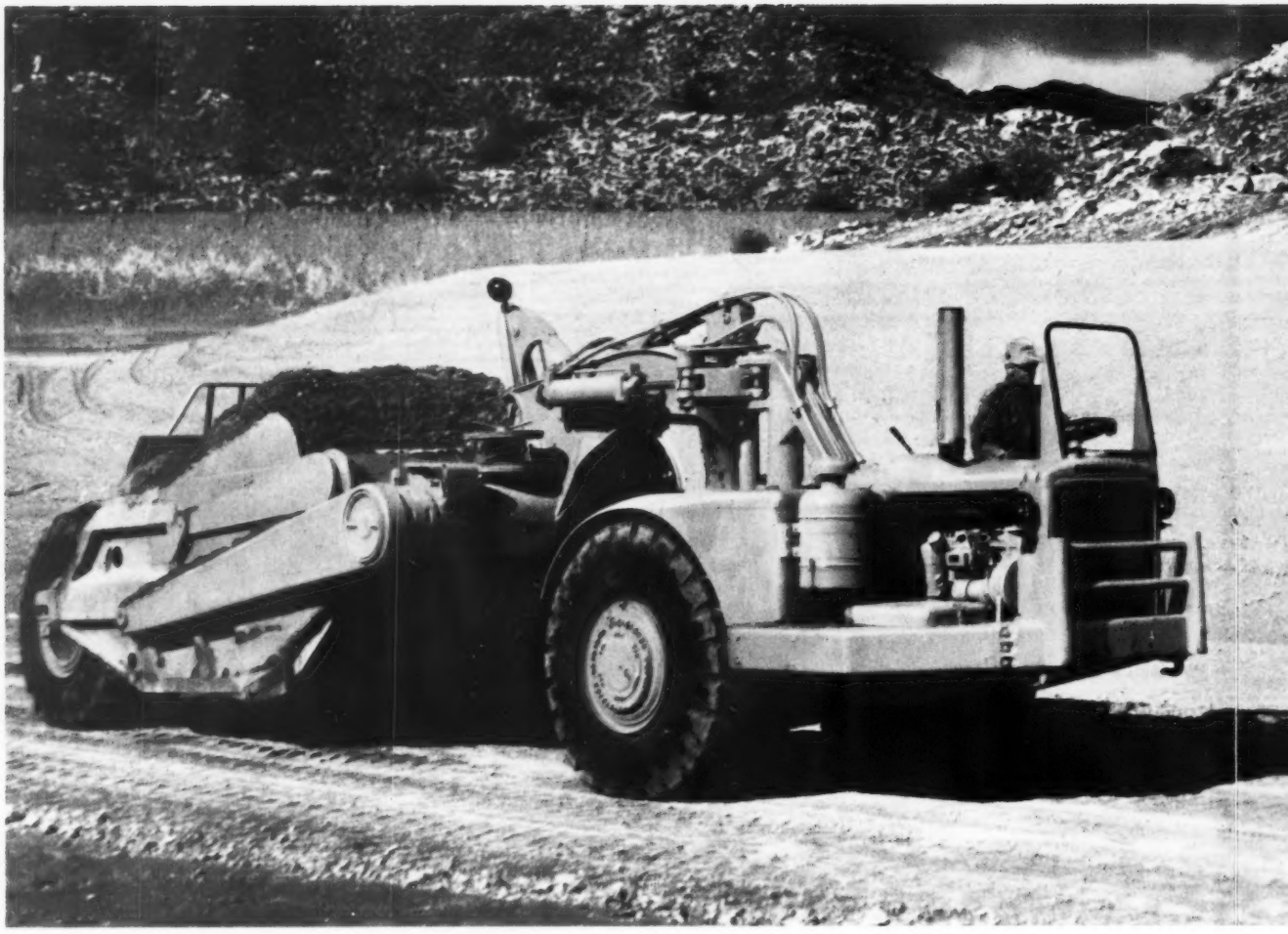

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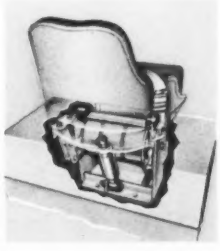

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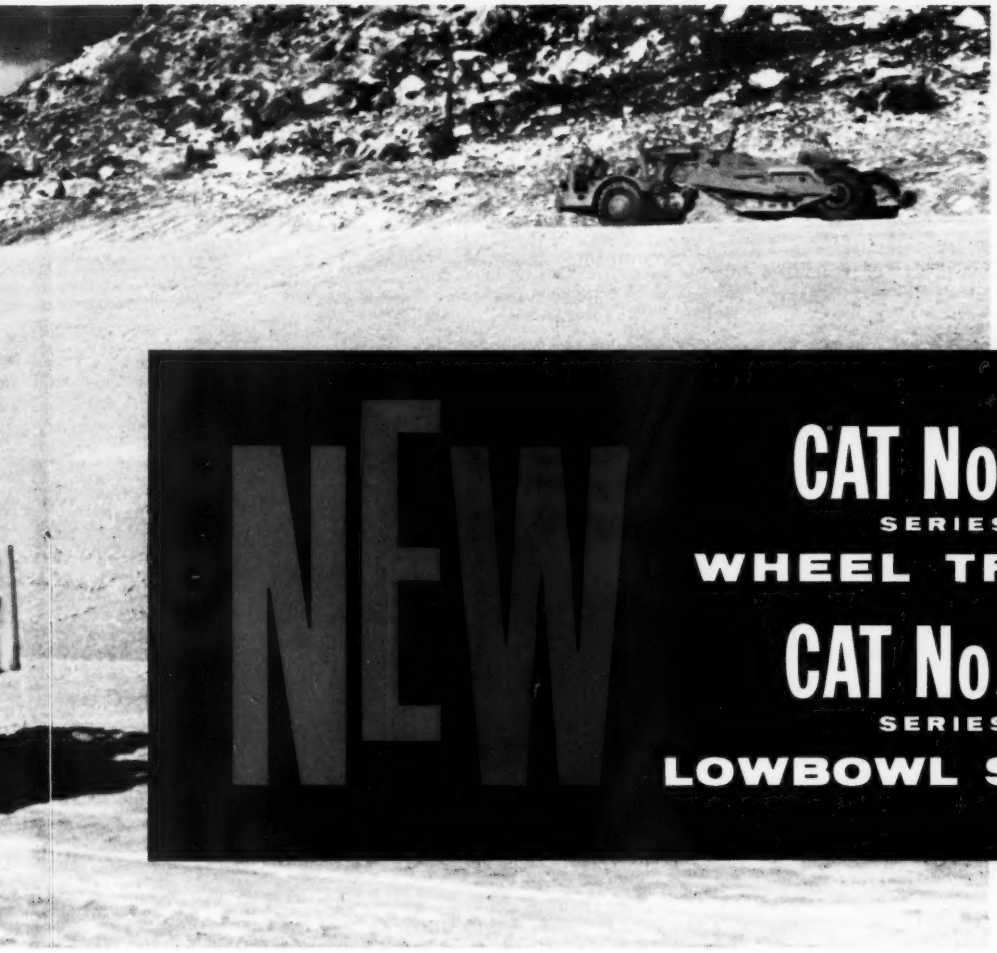

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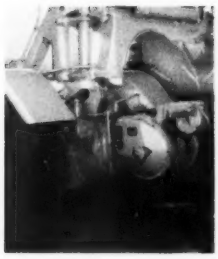

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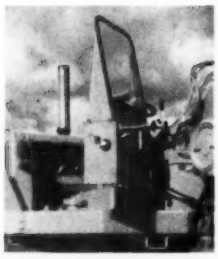

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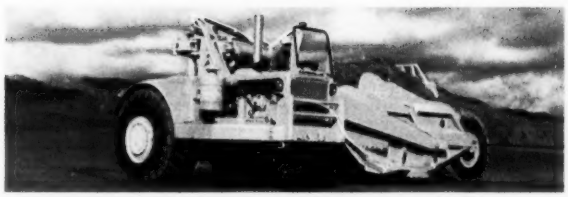

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Koichi Aki
Professor of Hydraulics
Tokyo University

Power Development in Japan

DURING THE LAST FEW YEARS MORE THERMAL plants than hydro have been built in Japan. The unit capacity of those thermal power stations is growing larger and larger and today some of them have a unit capacity of 220 MW to 265 MW. On the other hand, a number of hydro power plants with big reservoirs are now under construction. These facts indicate the present-day trend that thermal stations are increasingly supplying electricity for base load and hydro power plants for peak load.

At first, the Japanese power industry supplied electricity for lighting in late Nineteenth Century by the thermal power stations. But soon it became possible to transmit electricity over long distances and the harnessing of hydro power was begun. In the early stage "run-of-river" type plants were constructed. The daily peak load was met to the greatest extent by the help of small regulating ponds. The plants were designed at first to harness low-water discharge. With the increase in demand for electricity as industrialisation developed, the capacity of the plants was gradually increased to use more water and they are now harnessing about four to five times more than they had used at the start. This necessitated building supplementary thermal stations to meet the dry water season and in times when peak loads were in demand.

Thus the rate of construction for thermal stations became larger than that for hydro power stations. During the last few years the situation of both hydro and thermal-power plants has been changing, and the latter is taking the place of the former. The increase in the production of electricity has brought about certain changes in both quality and cost due to better techniques which improved the heat efficiency of thermal power stations by nearly 40 per cent. In 1935 the total installed capacity of electric power stations was 5,757 MW of which 3, 382 MW for hydropower and 2,375 MW for thermal-power and in 1958 it had risen to 18,366 MW in total, of which 10,798 MW was for hydro and 7,568 MW for thermal.

II

If 100 is taken as the index of proportion between the annual average price of coal and that of the general commodities in the year 1934 to 36, it is 70 in 1910 and rises upto 130 today. This indicates that the rising rate of price of coal is rather higher than that of the general commodities. Today in Japan average product of coal for one miner in a month is about 15 tons which is nearly the same we did in the days before the last war. Of course there has been a sign of worsening of the natural conditions of coal mines; we have tried to modernize our mining techniques, but also simultaneously there has been considerable improvement in working conditions. Particularly during the last ten years there has been a remarkable progress in productivity in industries. But it is not easy for a primary industry like mining to promote productivity compared with those achieved in manufacturing industries. And in recent years there has been a trend towards equalising the income of people of the country which promoted rapid increase of wages of coal miners who belonged to the lowest class in the past. Though we did modernize coal mining, still today the labour cost occupies about 50 per cent of production cost of coal. Inevitably therefore the price of coal will rise even in future. We made a brilliant economic progress during the past ten years and the annual rate of increase of our gross national products has been kept at nearly ten per cent during this period. But here we could see no particular change in the volume of production of coal, as is shown in the following:

PRODUCTION OF COAL IN JAPAN
(UNIT 1,000 MT)

Year	1938	1950	1954	1956	1958
Production of Coal	48,684	38,459	42,718	46,555	48,489

In recent years there occurred a gradual change in the pattern of coal consumption. It is less in domestic use and in small-scale factories and particularly in transportation which ten years ago was the top consumer of coal, where fluid fuel, such as oil, gas and electricity is now taking the place of solid fuel. In 1930 the consumption of coal in transportation occupied nearly 25 per cent of the total, but in 1958 it was drawn down to 9 per cent and it is believed it would be zero within the next 15 years. And there was great increase in consumption of coal in electricity generation. In 1950 it occupied around 9 per cent of the total consumption, but it increased to 15 per

cent in 1955 and to 19 per cent in 1959. It is estimated it shall be more than 40 per cent within the next ten years.

The changing of the pattern of coal consumption is basically due to the relative high price of coal compared with other competitive fuels. It is not easy to level up heat efficiency in small-scale use and the recent discovery of plenty of oil and natural gas is now accelerating the transference of coal to those fluid fuels. The consumption of coal is now concentrating to large-scale use where it can be handled more efficiently.

In 1951 the total installed capacity of the thermal power stations of the Electric Companies was 291 MW among which the capacity of the stations whose heat efficiency is less than 15 per cent occupied about 20 per cent of the total installation, and the capacity of those whose efficiency was between 20 to 25 per cent occupied 40 per cent of the total. And in 1958 the total installed capacity was increased to 5,880 MW where the stations whose heat efficiency is less than 15 per cent occupied only a few percentage and those whose heat efficiency is more than 30 per cent occupied nearly 40 per cent of the total. The largest unit capacity of the station in 1951 was 51 MW of which steam temperature was 450°C and steam pressure was 40 kg/cm², and in 1958 the largest unit capacity of generator rose up to 150 MW and its steam temperature to 550°C and its steam pressure to 125 kg/cm². By the end of 1960 the unit capacity of 265 MW, whose steam temperature is 570°C and steam pressure is 170 kg/cm² will be in operation. These modern highly efficient thermal power stations were originally designed for use of high quality coal and now we are promoting the study of construction of highly efficient stations for use of low quality coal to extend the full use of coal produced. Some of these have already been built. But in Japan under present conditions it is not easy to operate such highly efficient stations under full efficiency. It is because of the fact that still there remains the old pattern of production of electricity; that is, the majority of the operating hydro-power stations are of "run-of-river" type and it requires some amount of supplemental source to fulfill the demand of electricity.

As the author has already mentioned, the hydro-power in Japan has been developed originally as "run-of-river" type which was quite fitted to the natural conditions of Japan where we have plenty of precipitation and very rugged mountainous districts. But now we are constructing hydro-power stations with big reservoirs; we have already built several dams higher than 150 meters. The Ministry of International Trade and Industry announced in March 1960 the results of the fourth survey of hydro potential in Japan. According to this Report, it is estimated that the hydro potential will be about 35,370 MW and the annual production of electricity will be 130,090,120 MWh under stations at 2,372 sites. At the end of fiscal year of 1958, the total number of hydro-power stations were 1541; their installed capacities totalled 10,815 MW and their annual production came to 59,178,215 MWh. As a result of the Report 330 stations will be scrapped to build new type of power stations. Here we can say the unit capacity of the present-day hydro-power stations produced, for instance, in 1958 about 5,500 kWh during a year, but the annual production of electricity of unit capacity of the future stations will be 2,900 kWh. Today the annual working rate of the hydro-power stations is about 62 per cent, but that of the stations that are now planned will be 33 per cent. Thus we are trying to build hydro-power stations with big reservoirs to be able to operate as *supplemental stations*. The Report says that the majority of the hydro-power stations in Japan will now be built as "dam" type, so that large dams will be constructed in the head-water area and the original "run-of-river" type will remain less than 7 per cent of the total hydro-power.

This is the present-day trend of power development in Japan.

III

The rapid growth of Japanese economy brought certain changes in the pattern of power supply system of Japan. But it also created some problems for the other sectors of our economic activities.

Rice is a staple food in Japan and one-half of our arable land is used for rice paddy which occupies only seven per cent of the total land area of Japan located along the lower reaches of rivers. Naturally the granaries of Japan are situated along the low marshy lands where there have been need of flood control and drainage system for a long time. We have a long tradition of flood control, irrigation and drainage. But for increasing the production of rice, better drainage systems are needed as also more irrigation water. Even though we have been quite successful in increasing and stabilizing the yield of rice per unit area by our efforts for the past several years, yet the rapid growth of manufacturing industries widens the gap between the living standards of the agriculturists and industrial labour and thus the Government support for price of rice has to be bigger every year. These factors have also to be taken into consideration for further development of flood control works and other facilities such as drainage and irrigation.

As far as manufacturing industries are concerned, there has been a very remarkable progress of over 20 per cent of annual rate of growth of production during the past several years never experienced before. There has been an abrupt increase in the need for industrial water-supply and it is pointed out that today the difficulty of getting industrial water-supply

is coming in the way of the growth of industrial development itself. In some major industrial centers in Japan, underground water has usually been the main source of supply of industrial water; but today, following the rapid demand for water-supply, land subsidence appeared in several places to the extent of more than 20 cm of sinking of land every year. There is an urgent need for replacement of underground water by surface water. Rapid urbanization around large cities is also becoming one of the serious problems in Japan today; for instance, increase of population of Tokyo is nearly 300,000 every year. The domestic water supply is also becoming serious every year, and though a dam of 145 meters high was built only two years ago to store metropolitan water supply just near the city of Tokyo, the people of the city have to suffer severe restrictions in supply of water during last summer. More water supply is urgently needed in the major cities of Japan.

How to coordinate the demands of water in each sector of needs is a problem that needs to be urgently taken up. As far as hydro power development is concerned, the reservoir should be regulated to follow the demand of electricity and in these cases the river flow should again be regulated to adapt to the other needs of water supply. In general, due to the topographical and geological features of Japan, it is not easy to build dams high enough to be able to regulate the reservoir both to meet the demands for power generation and needs for flood control fully. We are afraid that if the reservoir is regulated fully to follow the needs for power generation, the peak discharge capacity of flood waters would sometimes be reached. This is the reason why comprehensive planning for river basin development is earnestly required. In Japan the Comprehensive Planning Bureau of Economic Planning Agency is in charge of promoting basin-wide development on the basis of unifying the various demands for water.

IV

Finally I would like to refer to the problems regarding the consumers of energy resources in Japan. Originally the industrialization of Japan was programmed to fit to the characteristics of the raw material resources available. As I have already mentioned, the surplus electricity inevitably produced in the high water season during midnight was supplied at cheaper rates and these particular factors created the present patterns of the industrial operation in this country. For instance, the six industries, such as carbide and lime, nitrogen, ammonium sulphate, caustic soda, iron and steel, aluminium and other metallurgy consumed 34 per cent of the total electricity supplied in 1956. And the operational efficiency of these factories could be estimated at less than fifty per cent throughout the year. Another reason which enabled the growth of the electro-chemical industry in this country was that investment for production facilities per unit power consumption was smaller in those industries than for any other major industry.

In my opinion, Japan has manipulated her energy resources and her limited amount of capital to the fullest extent. The social conditions in the past also permitted use of the excessive run-off effectively which would have been wasted otherwise. As the demand on natural resources increased further, however, as I mentioned earlier, the pattern of the use would have to be changed in accordance with technical development and improvements in living standards. We can say that the present pattern of industrial structure has been strongly characterized by the accessibility of the local resources.

Now we are confronted with serious problems coming on to a new stage. The structure of our energy supply is now changing. We have to exert our full efforts to prevent the rise of energy cost. But at the same time we also have to consider the features of the patterns of consumption. The cost of electricity is showing signs of rising higher every year and we have to notice the change in the supplying system of electricity. We have therefore to find the proper measures to reorganise the industrial operational system so as to correspond with the changing system of energy supply.

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Ervin E. Nonveiller
Head, Soil & Recleanics Foundation Division
Geoistrazivanja, Yugoslavia

Peruca Rockfill Dam in Yugoslavia

Treatment of a very pervious foundation

ON THE RIVER CETINA IN YUGOSLAVIA A ROCK FILL dam 180 ft. high has recently been completed. It will provide a storage lake of some 500 millions m^3 capacity. The energy output of an existing hydroelectric power plant on a down-stream stretch of the river will be improved and a new hydroelectric plant on a drop of some 800 ft. will generate about two milliards kwh per annum. Irrigation of fertile land will be effectuated in addition.

Detailed geological and geotechnical studies disclosed that the foundation rock on the dam site was not homogeneous, and a rock-fill dam with a narrow vertical clay core was selected. The foundation rock was very pervious in addition, and the main problem was its impermeabilisation. Extensive grouting with clay cement mixtures was necessary to attain an impervious grout curtain and to check the consumption of grout. Sometimes thixotropic mixtures with bentonite and mixes with sand were used. The total length of grouted holes amounts to some 540,000 ft. The curtain reaches depths of some 60 ft. below the rock surface and extends to some 2,500 ft. on both wings of the dam.

Geological characteristics of the site

Careful investigation was devoted to the geological and hydrogeological conditions of the region of the storage basin and of the dam site. Some 60,000 ft. of exploratory drillings were executed, underground water levels and their development as well as the discharge of numerous sources and springs around the borders of the basin were observed for years. The basin area consists mainly of cretaceous pervious limestone strata, covered on some places by impervious layers of marl of the Neogen series. In this reach the valley of the Cetina forms a syncline and the deeper, less pervious, dolomite strata of the lower Creta series crop out on the surface of the flanks of the basin. This forms a reliable natural barrier against seepage on the flanks of the basin, the only way of escape of stored water remaining under the dam and around its abutments through the pervious limestone formation.

These cretaceous limestone strata are heavily fractured as a consequence of tectonic movements of the region. Water has penetrated along fissures and has dissolved the lime, producing cavities and canals, and a very pervious formation resulted. Some of these cavities had been successively filled up with a highly plastic clay consolidated under heavy thrust. Nevertheless the whole formation is very pervious because many seepage lines exist characteristic of all carstic regions, where some of the filled cavities were washed out again.

It was essential to find means to prevent heavy water losses from the storage through existing canals and cavities under the dam and around its abutments, which could eventually increase due to subsequent erosion of other potential seepage ways which actually are filled with clay.

The treatment of the dam foundation was the key problem of the scheme, the appropriate solution of which was important not only for this dam, but for many other schemes, since about 30% of the potential water power resources of Yugoslavia are located in similar carstic regions.

Design of the Dam

For the location of the dam a stretch of the river was investigated passing through a narrow gorge. On a part of the gorge the mechanical properties of the rock were good so that a concrete dam could have been built, but the idea was abandoned because there the permeability of the foundation was very high. On the upstream end of the gorge the left abutment consists of bauxite and bauxitic clay and that part of the foundation is less permeable; the rest of the profile consists of broken and fissured limestone, the seams of which are filled with stiff clay and the rock is less permeable than on other stretches. At this place only a rock-fill dam could be considered because of the heterogeneity of the foundation (Fig. 3).

In the construction area unlimited quantities of limestone of appropriate quality for the construction of a rock-fill dam were available. The quarry was located on the right bank of the river at an elevation corresponding to some 2/3 of the height of the dam.

Fig. 1.

Relatively small quantities of clay were available at a reasonable distance from the site, located in the river valley upstream from the dam.

Two types of dam were considered in previous stages of design:

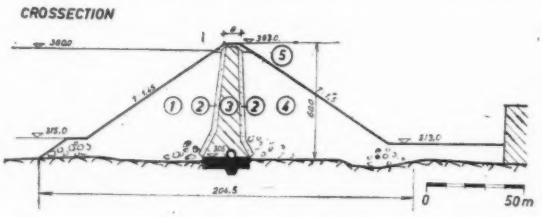
— rock-fill dam with upstream impervious blanket of bituminous concrete,

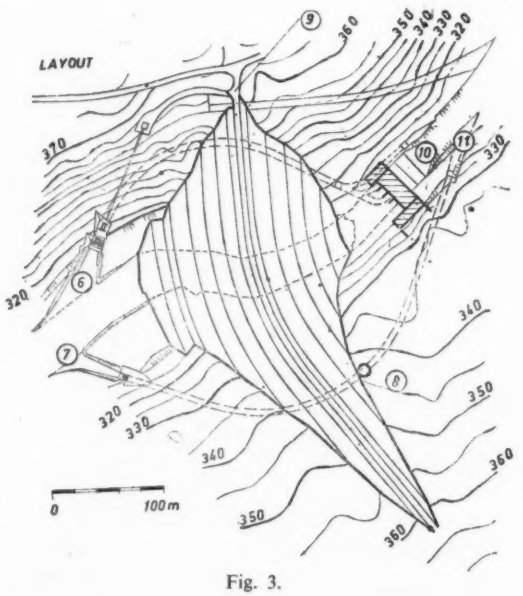
— rock-fill dam with central clay core (Fig. 3).

The construction of a dam with clay core proved to be more convenient and it was selected for the final design.

The properties of the clay were investigated in the laboratory and the following characteristics were established:

— liquid limit: 58 – 82%;
— plasticity index: 35 – 54%,
— AC clasification: anorganic clay of high plasticity, CH,
— optimum moisture content, by standard Proctor





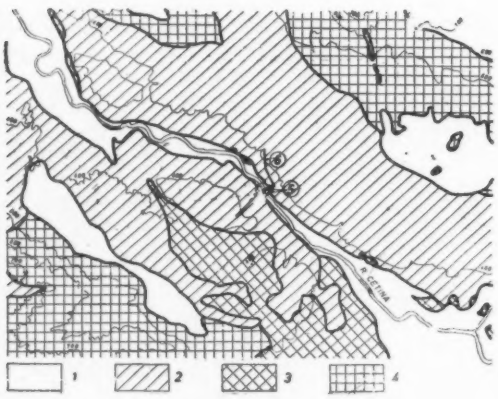


Fig. 2.

Fig. 3.

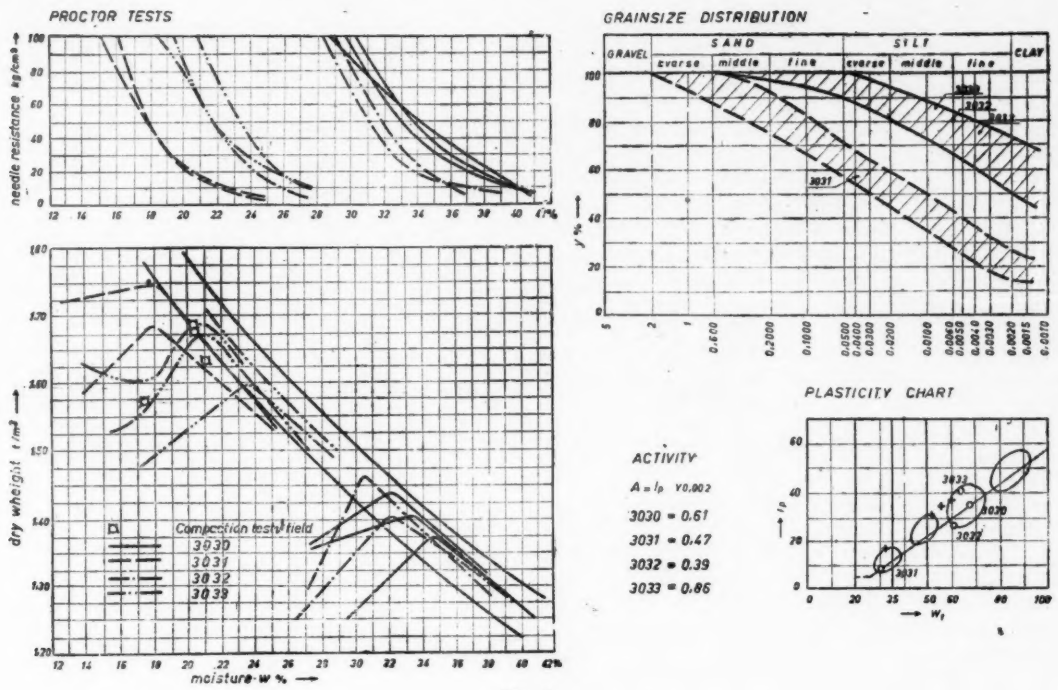


Fig. 4.

procedure: 20 – 22%,

— optimum dry weight 1.5 – 1.7 t/m³,

— shearing strength, triaxial test on precompacted samples at optimum moisture content s = between 9.0 ÷ 0.165 and 3.0 ÷ 0.375 t/m²

— coefficient of permeability $k = 5 \div 8.10^{-9}$ cm/sec.

Representative test results are shown in Fig. 4. The properties of the clay from the borrow area were examined on a test field, on which four strips were compacted with sheep's foot rollers having a foot pressure of 27 kg/cm². The results conformed to the laboratory tests and are shown on fig. 4. Based on this result the specifications for the construction of the core were elaborated.

The clay was rolled with sheep's foot rollers of 27 kg/cm² specific foot pressure. The layers were 10 in thick and at least 12 passes of the roller were specified.

A statistical elaboration of the average moisture content and dry weight of the clay core are represented of fig. 5.

The properties of the rock for the fill were investigated in the laboratory on representative sand fractions on which particularly the angle of friction was studied. Triaxial tests revealed the relation between the dry weight and the angle of friction as represented on fig. 6. From representative samples of quarry blast rock as well as from temporary checks of rock from the fill the grain size distribution was determined as

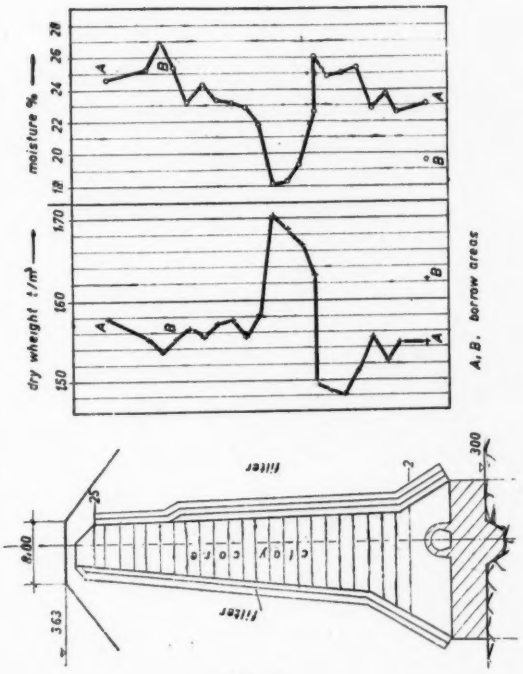


Fig. 5.

shown on fig. 6. Based on these test results the following values were chosen for the stability analysis:

dry weight	1.75 t/m³
angle of friction	Y=45°

The specifications limited the content of small fractions of less than 20 mm grain size to 10% by weight for the upstream shell, and to 20% for the downstream fill. The fill was placed by dumping in lifts not less than 18 ft. thick. It was compacted by sluicing with hydraulic jets, the water volume amounting to four times the volume of placed rock. This procedure gave a well compacted rock fill with most of the fine particles washed into the voids between bigger rock fragments.

The dry weight of the actual fill was established as 1.88 tons per cu m.

This was done by determining the weight of the rock placed in a trial fill of regular shape.

The foundation of the impervious core of the dam was given special care. A massive concrete block was inserted between the foundation rock and the clay core in the river bed section; its surface was above the downstream water level, to enable the construction of the lowest portion of the core on a completely dry surface (fig. 8 and 9). On the abutments the core was laid in a cut-off trench excavated through the upper layer of fissured limestone rock. The fissures of the rock on the surface of the trench were cleaned and sealed with concrete or with gunited mortar, to prevent any chance of regressive erosion on the contact of the core by water percolating through fissures which could possibly remain open after the foundation was grouted.

On both sides of the core transition filters were laid; their grain size distribution was checked by laboratory tests. Due to the high clay content of the core material the application of traditional filter rules would have necessitated filters with more than three layers. Laboratory tests were performed and a three layer filter was found fully satisfactory and safe against any possibility of erosion. The grain size distribution of all materials used in the dam are shown on fig. 10.

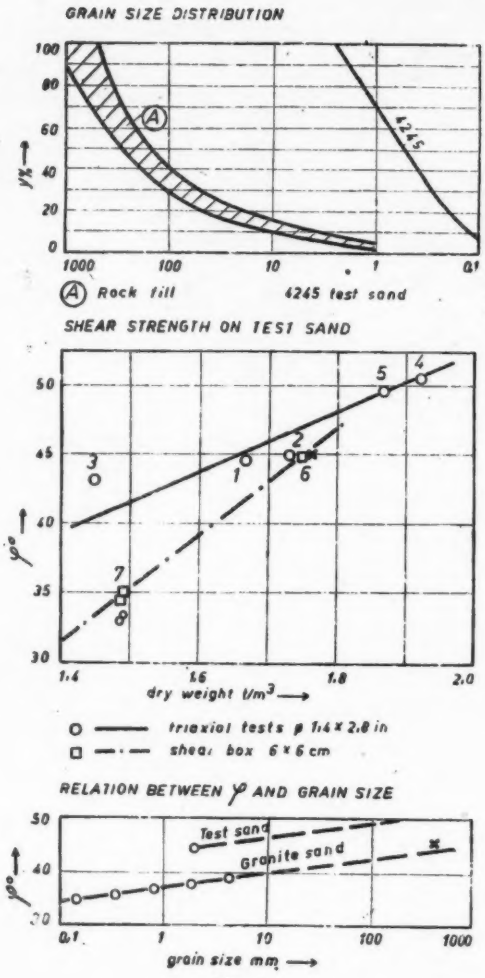


Fig. 6.

The stability of the u/s and d/s slopes was computed with circular, plain and composite convex sliding surfaces. It was found that in this case convex sliding surfaces were the most dangerous (Fig. 7).

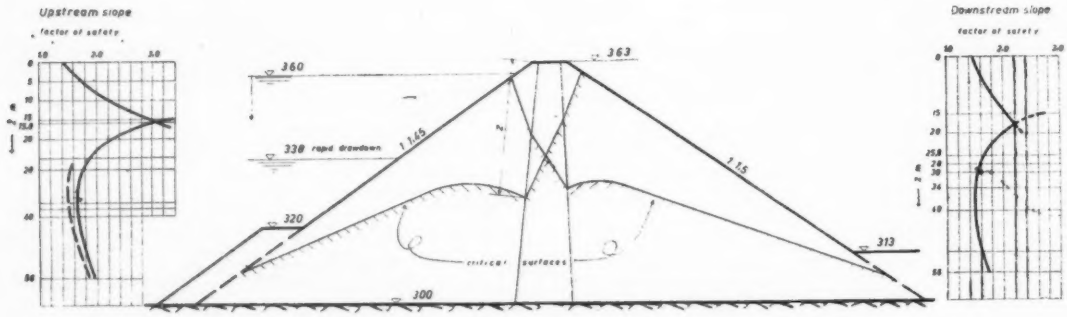


Fig. 7.

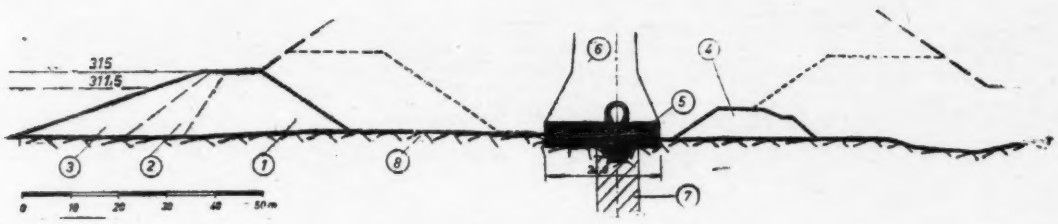


Fig. 8.

Construction of the Dam

The construction of the dam was highly mechanized. For the excavation of the rock in the quarry the bench method was applied. Every single shot yielded some 20000 m³ of loose rock. The rock was loaded by electric driven power showels (one of 3 cu. yds. and two of 2 cu. yds. capacity), into Euclid rear-dump trucks of 15 t capacity. With about six Eucs in service some 4000 m³ of rock fill could be handled daily in two shifts. Similarly the clay was excavated and loaded in the pit by a Diesel driven power shovel of 1½ cu.yd. capacity, and transported to the embankment by Foden dumpers of 10 t capacity. There it was spread in layers by bulldozers and rolled to the required density.

A field laboratory was established for the running control of the placement of the fill and for occasional checks of the properties of the materials.

The foundation excavation and the construction of the concrete block in the river bottom were executed under the protection of two cofferdams. These cofferdams consisted of rock and earth fill dumped into running water (Fig. 8 and 11).

The treatment of the slopes of the dam was very simple. On the upstream slope heavy rock for protection against wave erosion was dumped in a layer some 10 ft. thick without any further treatment of the slope surface, which remains rough as seen on fig. 12. On the downstream slope quarry run rock was dumped and sluiced tangentially by heavy water jets; any material which was not stable, on the slope was washed down, thus yielding a surface which can not be eroded subsequently even by very heavy rain (Fig. 13).

Fig. 9. Foundation of Dam.

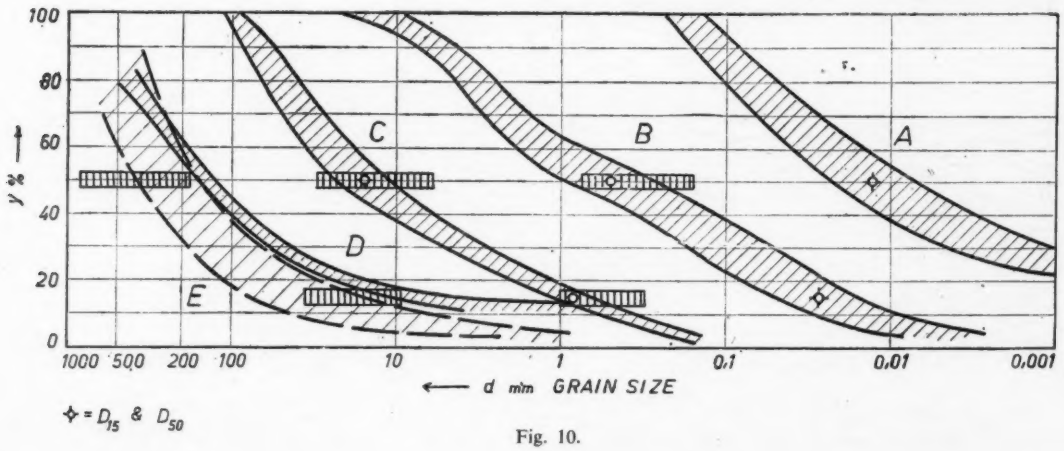


Fig. 10.

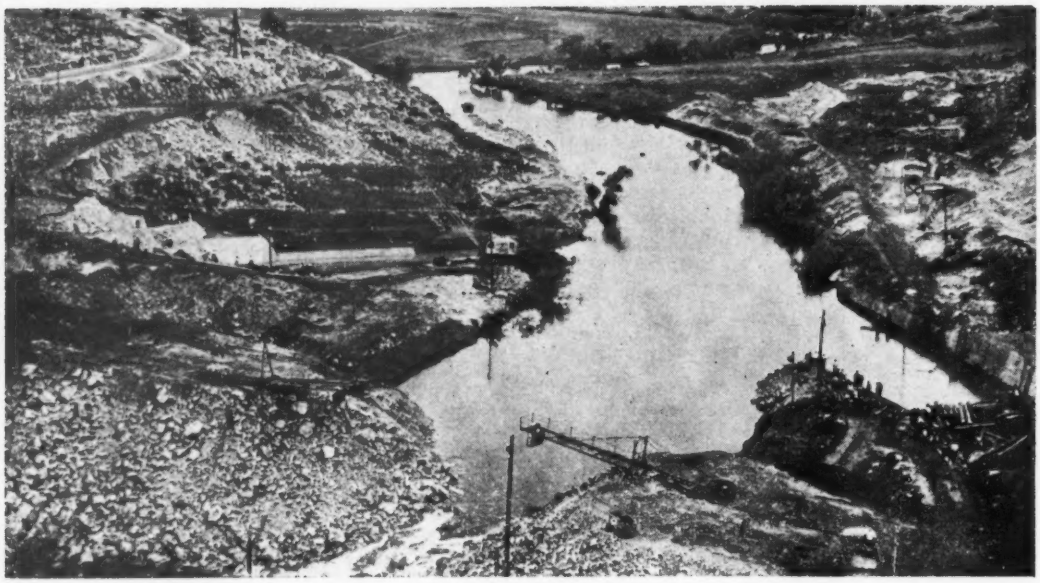
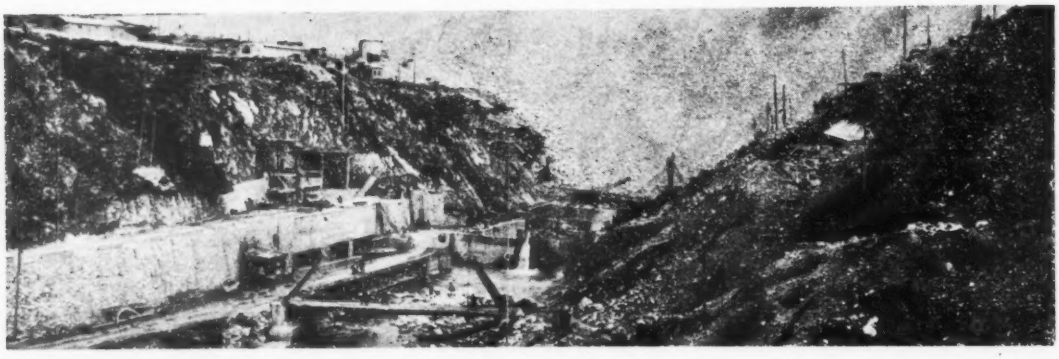


Fig. 11. Closure of u/s cofferdam.

Fig. 12. Upstream slope completed.

Fig. 13. Downstream slope of dam.



Performance of Dam

The settlement of the core as well as of crest and slope surface settlement points is being observed continually, a trigonometric net of reference monuments on the abutments upstream and downstream of the dam has been established. From theese monuments the movements of surface settlement points on the slopes and on the crest of the dam is being checked. In the clay core two settlement gauges consisting of short pipe sections with reference points for measurinp the settlement of the core at different elavations /type U.S.B.R./ have been installed. The results of the observation carried out to date have shown that the post construction settlement of the dam amounts to 11 cm during the two years after end of construction.

The downstream deformation of the dam after filling the reservoir has been negligible.

Fig. 14. View on quarry, benching method was adopted

Foundation treatment

The permeability of the foundation rock under the dam and on its wings varies erratically from point to

Fig. 16. Rock-fill was sluiced with heavy water jets.

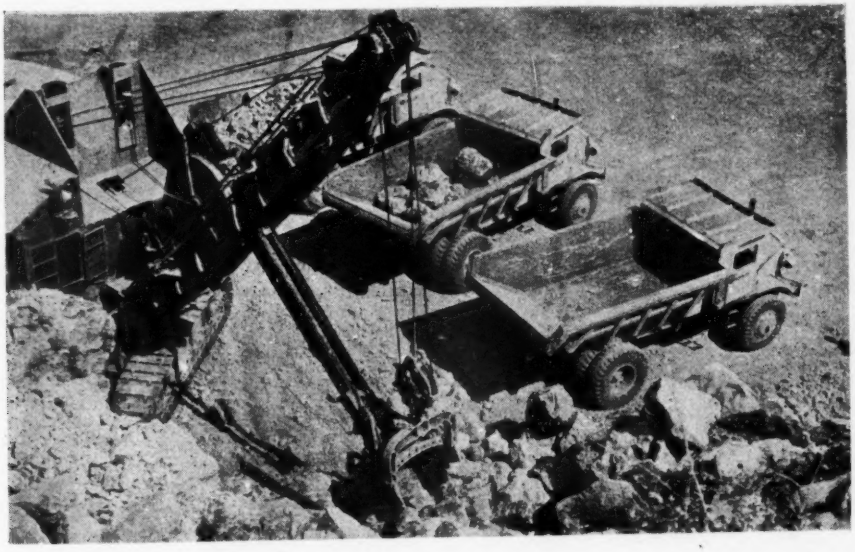


Fig. 15. Electro-shovel loading rock into Eucs.

point. Many investigation core holes were drilled and permeability tests performed on 5 m long stages. The permeability of the rock ranges from about 21/min, m at 10 kg/cm2 pressure (2 LU) to about 50 LU, the statistical average being about 20 LU. This is an exceptionally high permeability and an extensive curtain had to be envisaged to intercept as much as possible of the water percolating under the dam. This so much more because the danger had to be considered, that some tight fissures, actually filled with clay, could be washed out subsequently, thus causing progressively increasing heavy water losses under the dam.

Tests were carried out to find the most convenient solution of the following features of the grout curtain:

— most convenient grout mixes,
— arrangement and spacing of grout holes,
— grout pressure.

A few grout test fields were carried out to that purpose. First normal cement suspensions were tried, but without any success because of uncontrolled flow of grout through open fissures. An extensive program of laboratory tests was then carried out with clay-cement grout mixes. A highly plastic clay was available at the site from the borrow pits for the core material.

Fig. 17. Aerial view of completed dam, quarry area in background right.

Activated with about 1% Na_2CO_3 it gave stable suspensions with cement, and with the addition of some bentonite even thixotropic suspensions. A wide range of different mixing ratios of cement, clay and water was investigated, and the results were represented in triangular plots (Fig. 18) on which lines of equal apparent density (measured by means of an appropriate areometer), the limits of thixotropic and of stable mixes, as well as lines of equal viscosity were drawn. Such diagrams were very useful for the selection of most suitable mixes for different field conditions.

A point of concern was the strength of clay-cement grout mixes. To simulate actual field conditions cylindrical samples were prepared by filtering grout suspensions under pressure in a special device. After curing under controlled conditions the unconfined axial strength of the samples was established. It gave an idea of the strength which the grout can be expected to attain when injected into the fissures. Some of the results are represented on fig. 19.

The permeability of the grouted mixes was tested on the same samples, and was found to be around $k = 10^{-9}$ cm/sec.

When the use of clay cement grouts was suggested there were objections because it was suspected that the grouted mix would shrink considerably when subject to drying. The linear shrinkage was measured on the above mentioned cylindrical samples after drying and it was found to be less than 3% even with mixes containing only 10% cement. In fact the grouted mix cannot be subject to complete drying because of the natural moisture contained in the soil, and therefore it was found that shrinkage could be disregarded.

The arrangement and spacing of the grout holes were studied on grouting test fields. On some of them cement grouts and cement grout with bentonite were used. On test field E clay-cement grout was applied. On the fields A – D two rows of holes were grouted, on field E a row of staggered grout holes between the external rows was added. On fig. 20 the arrangement of the holes on some test fields are shown, and on Table I. the results obtained are presented.

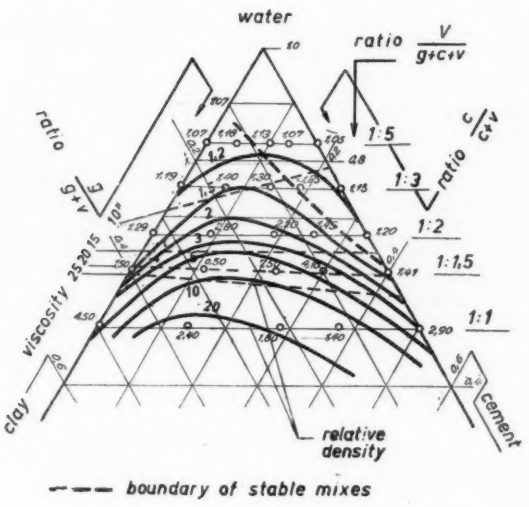


Fig. 18.

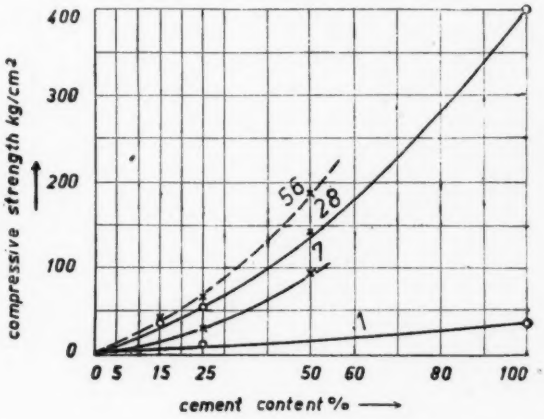
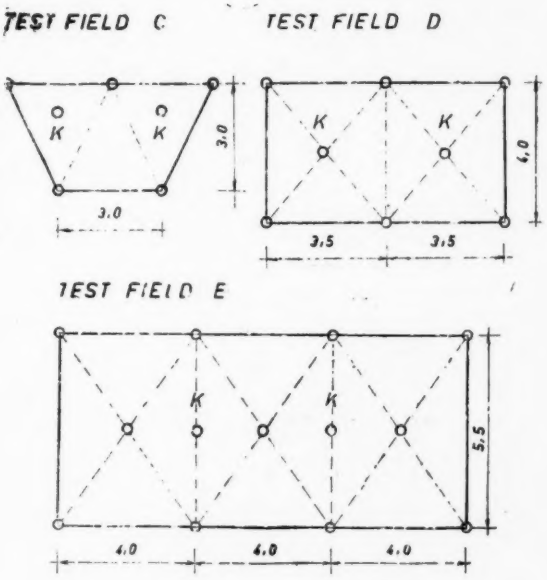


Fig. 19.



Field	C	D	E
Drilling lin. m.	360	400	560
Area sq m.	27	56	132

Fig. 20.

Table I

Test Field	C	D	E
grouted volume of rock m3	540	1120	2640
length of grout holes per m3 of grouted rock m	0,67	0,36	0,21
spacing of holes m	3,0	3,5	3,50
average permeability of rock LU	16,8	12,6	38,1
grout consumption kg/m3	294	135	137
cement consumption kg/m3	270	130	34
specific grout consumption kg/LU, m3	17,5	10,7	3,6
average permeability of rock after grouting LU	1,34	1,38	1,22

1 LU = waterloss of 1 lit/min on 1 m of hole at 10 kg/cm² pressure.

Based on such extensive laboratory and field evidence it was eventually decided to grout the curtain with mixes containing 75% of clay and 25% of cement. When the grout take in particular stages was excessive thixotropic mixes with the addition of up to 5% bentonite, and sometimes with sand replacing part of the clay, were adopted. With these thixotropic mixes it was possible to check the consumption of the grout and to fill voids and fissures only in a reasonably limited area around the grout hole.

The grouting station is represented schematically on fig. 21. For the preparation of grout mixes un-

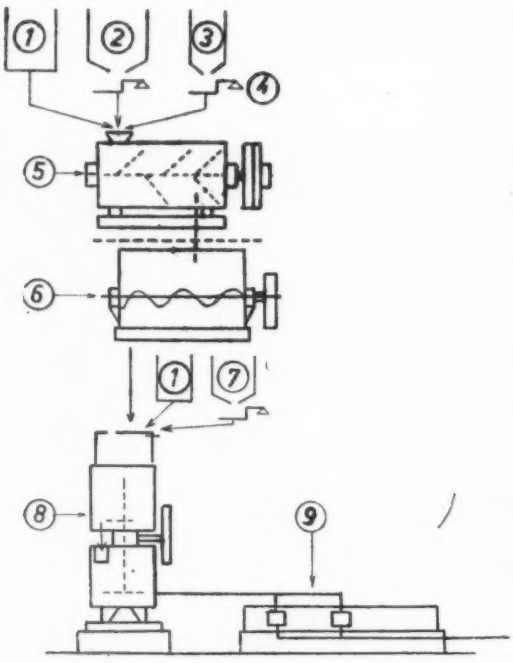


Fig. 21.

Fig. 22. Comparison of mix treated with paddle mixer and with high turbulency mixer.

processed clay in clods from the pit was used. The mixes were prepared in two stages. First a basic suspension of clay and water (ratio 1:1) was mixed in very efficient mixers constructed specially for that purpose. About 1% of Na_2CO_3 was added for stabilisation of the suspension. When required bentonite was added to this basic suspension. Natural, pit run, bentonite in clods was used. This basic mix was conveyed to high turbulency mixers where cement and water was added for preparation of the actual grout mixes. These consisted of 25% cement, 70—75% clay, 0—5% of bentonite and 1% of Na_2CO_3; the mixing ratio with water was 1:6 to 1:1. The high efficient mechanical activation with the high turbulency mixer is best illustrated by fig. 22.

Hydraulically driven piston pumps (fig. 24) were applied for grouting. The grout was pumped to the grout holes to a distance of up to 1000 ft through pipes of 1¼ in I.D. without any difficulty.

Grout pressures increasing with depth from 10 kg/cm² at 10—25m depth to 40 kg/cm² at 200m for the external, and to 60 kg/cm² for the inner row of grout holes, were specified.

Rotary rigs with hard metal bits were used for drilling the grout holes.

The contractor had free hand to decide whether the grouting operations should be executed from top to bottom or vice versa. Generally the first method was applied because the rock was heavily fractured involving the danger of caving and blocking the drilling-rods or the grouting pipes and packers. Where better rock was encountered the method of grouting from bottom to top was equally successful. The specifications provided for 5 m long grouting stages, exceptionally, when the permeability was low, stages up to 10 m long were grouted.

Grouting was carried on in every stage until satura-

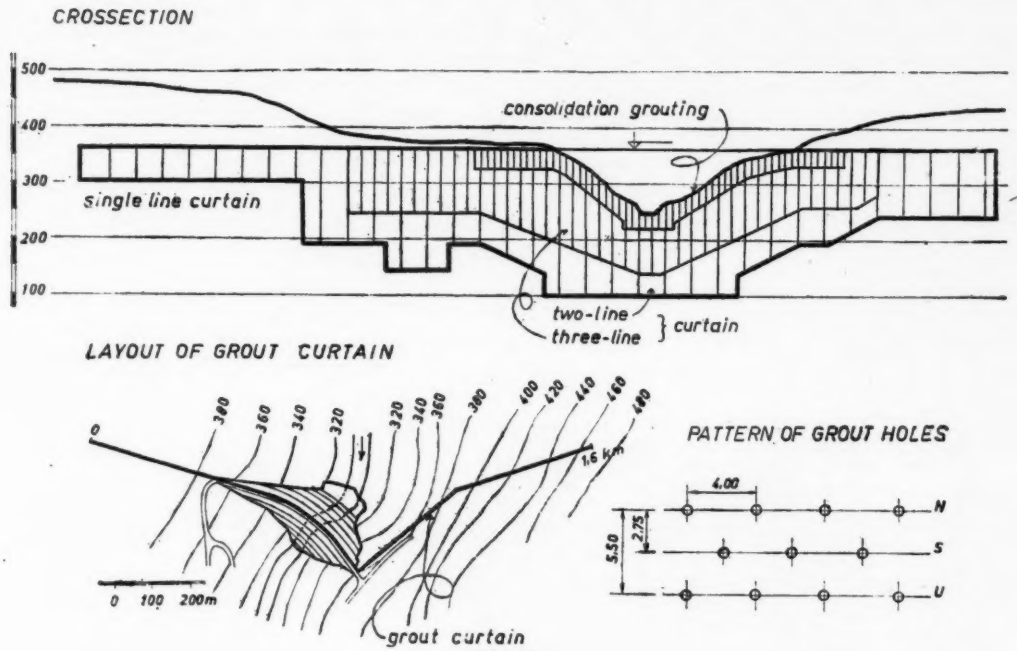


Fig. 23.

tion at the specified grout pressure was attained, (i.e. less than 30 lit. grout take during the last 30 min). An exception was made when saturation could not be achieved at takes of more than 1500 kg/m even with the thickest thixotropic suspension. In such instances the grouting process was interrupted; it was resumed after the grout had ample time to set and thick mixes with sand were grouted.

It is interesting to note that the grout suspensions develop a considerable strength immediately after grouting is completed provided that saturation is achieved. This is in agreement with the laboratory evidence on grouted samples. So the use of clay cement mixes does not require a postponement of subsequent grouting operations to allow for development of strength.

The trace and the crosssection of the grout curtain are shown on fig. 23.

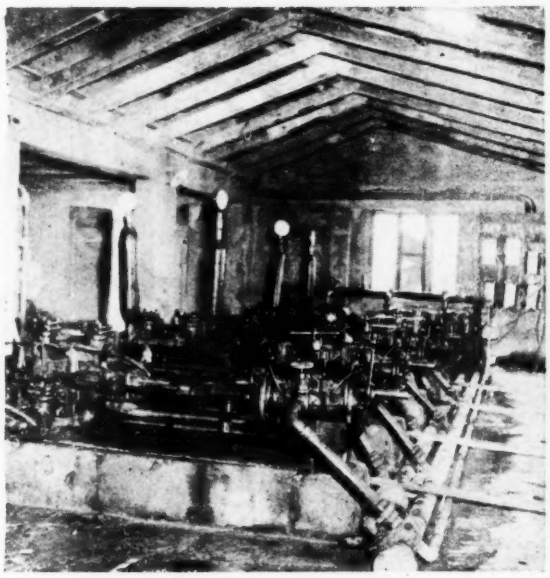


Fig. 24. Grout pumps.

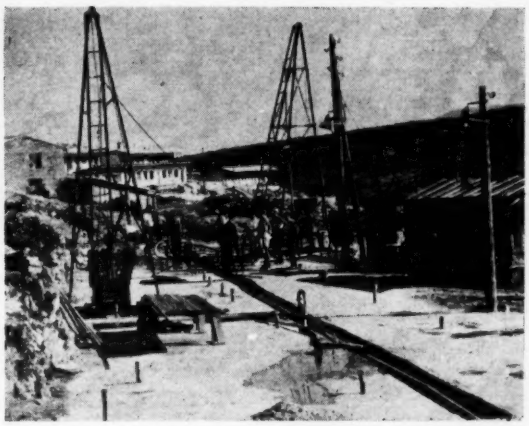


Fig. 25. Grouting site with drilling rigs.

Altogether about 540,000 ft of holes were grouted. The average grout consumption was about 300 kg/m of dry substance (cement & clay). On figs. 26—29 the results of permeability tests before and after grouting, as well as the grout consumption in different stages of the grout holes are represented for a part of the grout curtain. It is evident that the permeability of the rock was greatly reduced after the external holes of the curtain were grouted. The grout take in the central holes is also reduced compared to the external rows of grout holes.

Following the foundation trench of the core a concrete gallery was constructed from which the consolidation grouting of the upper rock strata was performed. At the same time it provides a facility for checks of the tightness of the foundation, and for additional grouting under the dam if needed. After the first filling of the basin a few leaking spots were detected in the gallery and cured.

The overall result obtained with this extensive and very expensive grout curtain has proved to be very satisfactory. During the filling of the basin piezonatric levels have been observed on the surroundings of the dam and on the wings of the curtain. On

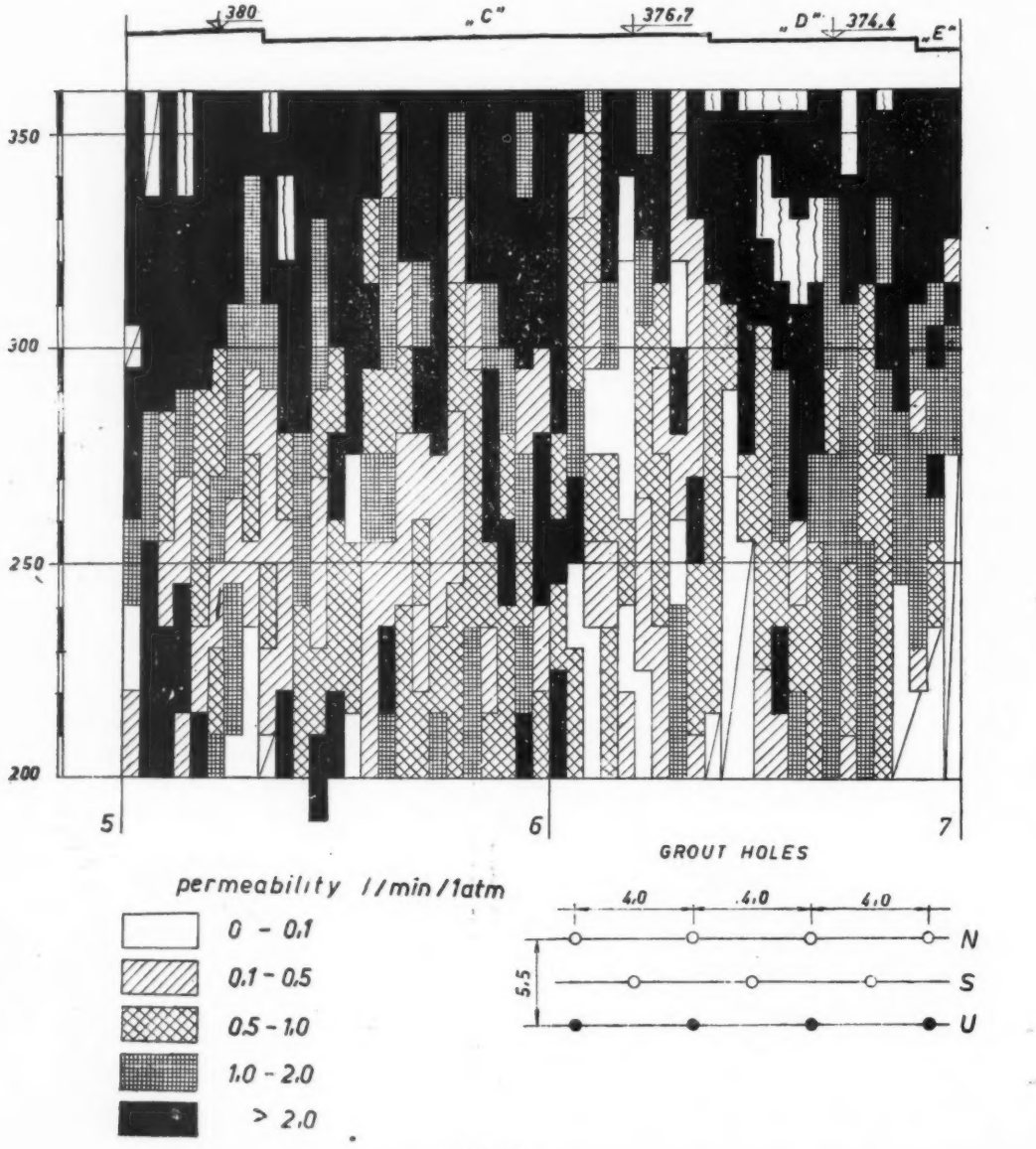


Fig. 26.

some small springs on the banks of the riverbed downstream of the dam a small increase of the flow was observed, but the total discharge of all these springs is insignifant.

From this evidence it can be concluded that the grouting works on this dam were a full success.

This positive experience, on the first grouting work of such extent for a big storage in the carstic region of Yugoslavia is of particular importance for the future development of its potential hydropower resources of which 30% are in the carst.

Leading with the field investigations for this scheme was Elektroprojekt, Zagreb, which has done the design of the scheme and of the grout curtain. The rock fill dam was designed by "Goistrazivanja", Zagreb, which have executed most of the invetigation drilling.

Contractor for the dam and adjacent works was Konstruktor from Split. The grouting works were executed from Elektrosond, Zagreb, on the right bank and from "Geoistrazivanja" on the left bank. Consulting engineers were Mr. Ervin Nonveiller, "Geoistrazivanja", for the rock-fill dam and Mr. Luka Mladineo. "Elektroprojekt", for the grout curtain and for the adjacent works. Most of the laboratory investigation for the grout suspensions were done by "Geoistrazivanja".

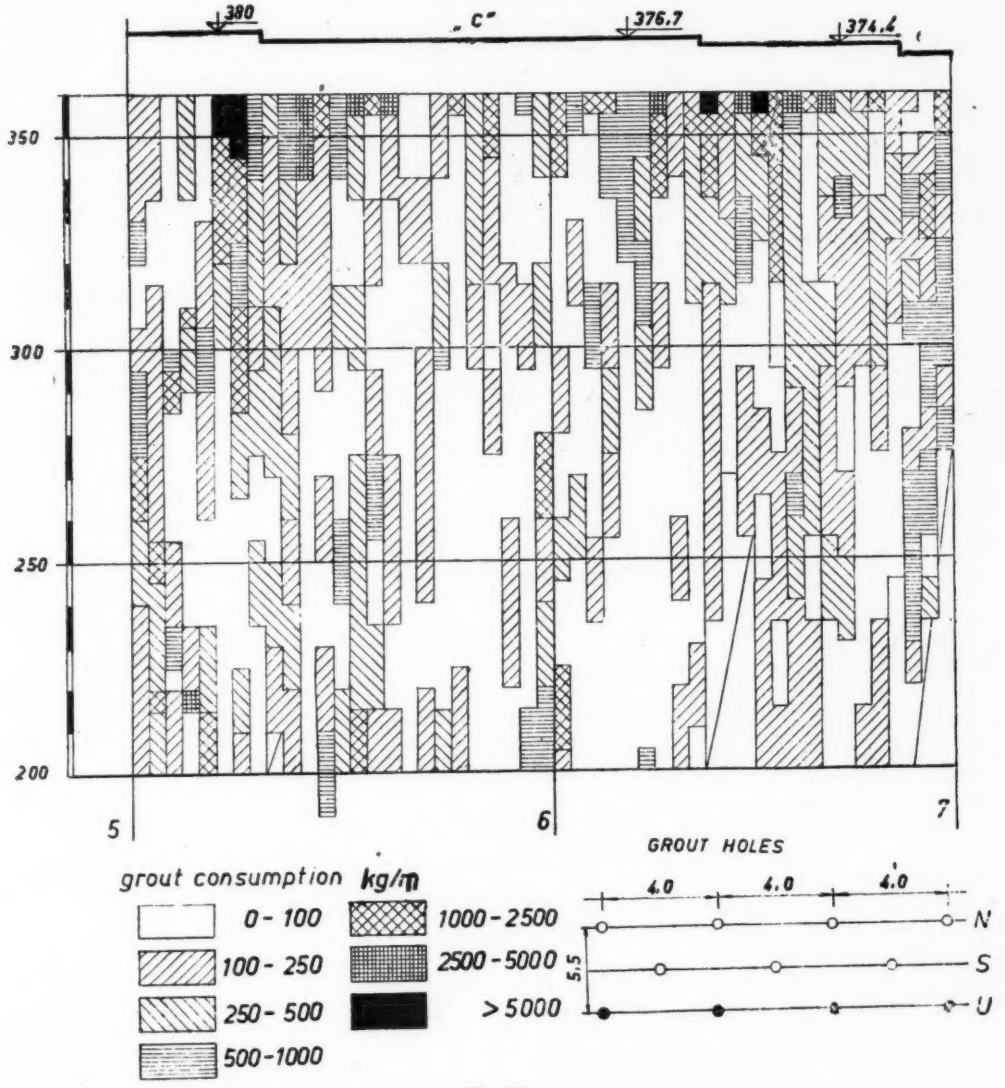
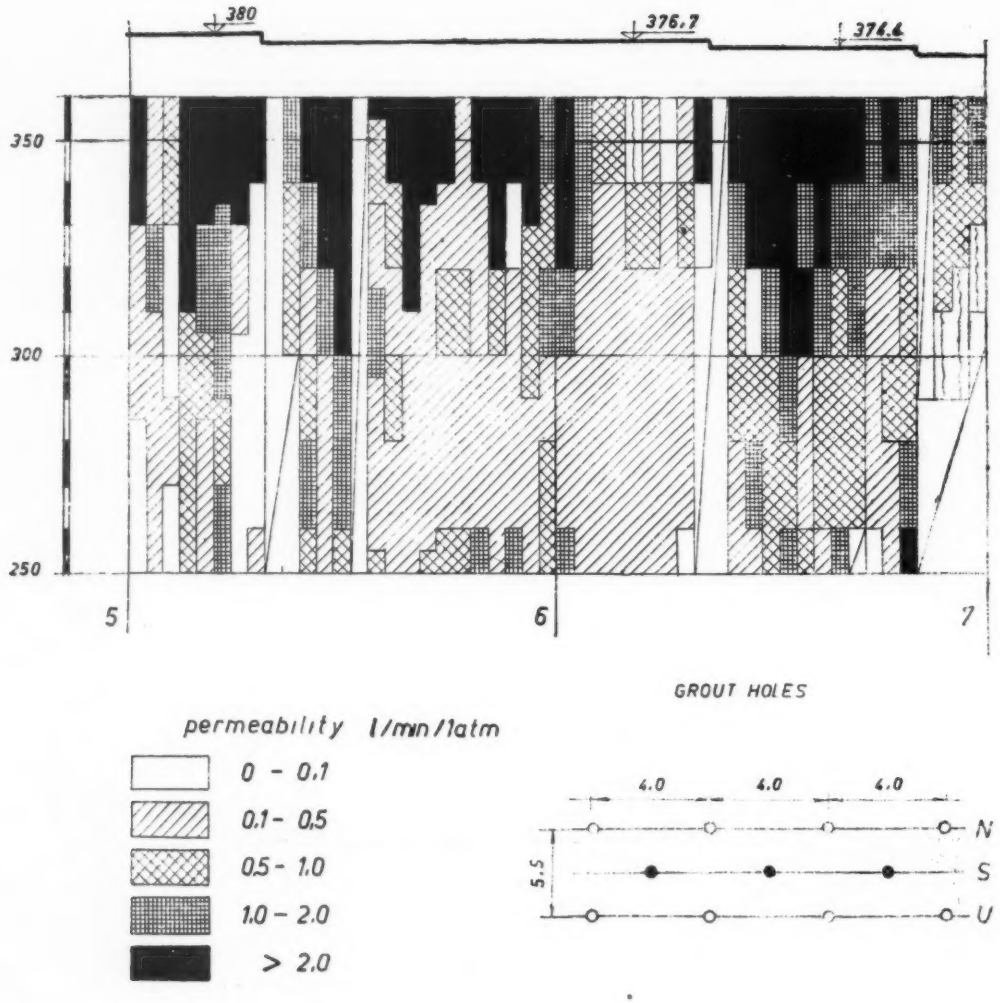


Fig. 27.


380
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GROUT HOLES
permeability l/min/1atm
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0.1 - 0.5
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1.0 - 2.0
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Fig. 28.

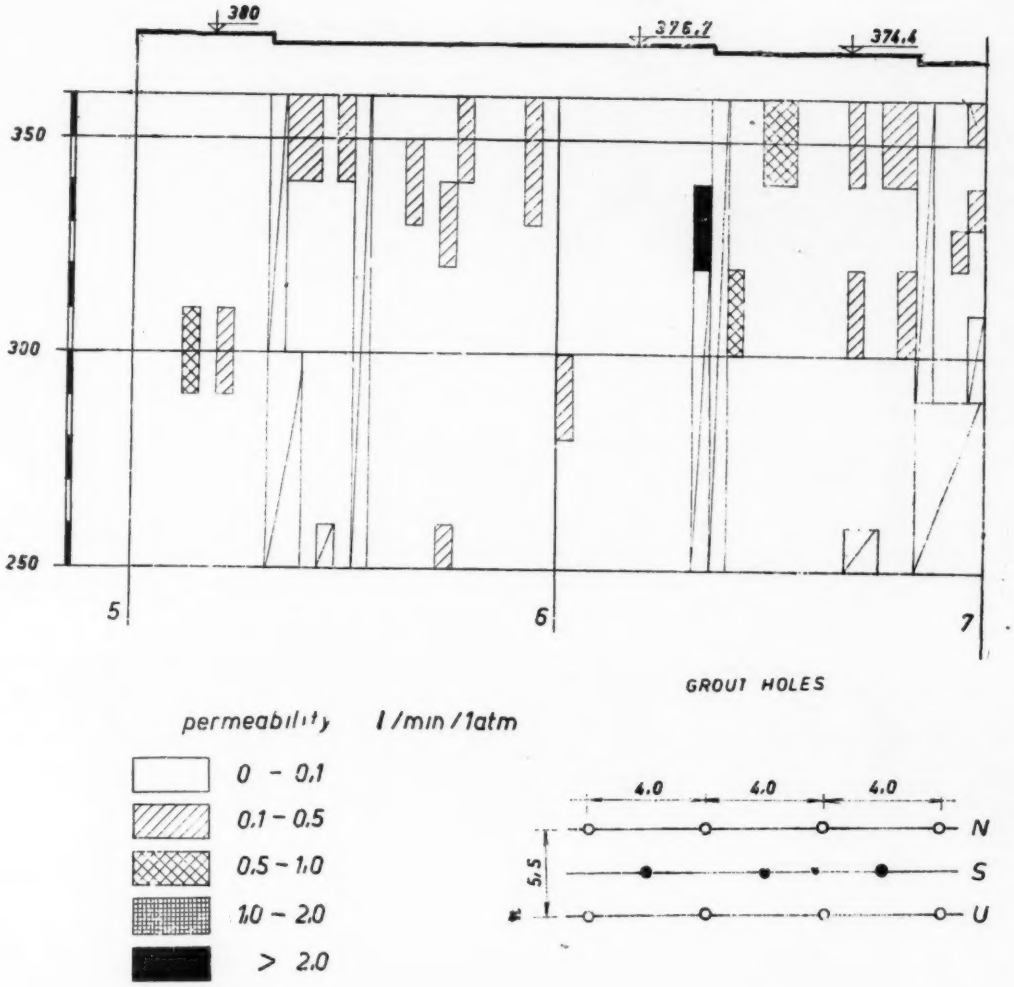
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Fig. 29.

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Dr. N. K. Bose
Formerly Director,
River Research Institute, W. Bengal

Flood Control: A Human Problem

OF LATE FLOODS HAVE POSED PROBLEMS THAT ARE more human than technical. Floods are as old as civilisation. As flood-plains offer better opportunities for cultivation, water-supply and water transport, human concentrations have been mostly in these areas. To protect in turn these establishments river flows have always been controlled by various devices. Embankments and dykes have been the most common form of protective measures adopted since early days. With vigilance and care these have served their purpose more or less successfully, though breaches with consequent devastations were not unknown. Human concentrations have usually tried to locate themselves at safe distances from these embankments, though due to population pressure this has not always been possible. With the development of technical knowledge and skill other measures for flood control were undertaken. Retention dams in the upper catchments of the river were the next step. Multi-purpose possibilities of this device were soon recognised and pressed into service. With the promise of increasing safety in the flood-plains, encroachments increased in tempo and most of them were unco-ordinated and haphazard. In consequence losses due to floodings became much more widespread and intensive.

Not only settlements in the flood-plains have been unco-ordinated, they have cut across the natural drainage of the country. In many instances they have been built on the drainage lines of the districts, and civil authorities have been inoperative partly due to lurking sympathy with the settlers and partly due to insufficiency of existing powers, and laws' delay.

We are informed by the weather experts that precipitations such as those of 1959 or 1956 in the Gangetic West Bengal are not infrequent. They occurred a number of times during the last half a century. We are told that the flood damages during 1959 or 1956 ran into several crores of rupees whereas those of 1913 or 1935 barely exceeded a crore. 1943 floodings were exceptional due to other factors as they interfered with "war efforts". Floods of North Bengal have also been no exception to this. In September 1922 a devastating flood overtook the whole of the North Bengal between the rivers Ganga and Brahmaputra. Continuous precipitation for days sent down torrential currents through the numerous streams that run south from the foot-hills of the Himalayas overflowing their banks and inundating the countryside. This vast sheet of water rolling down the plains was first obstructed by the railway embankment from Santahar to Parbatipur and then by the high levels that ruled in the two outfall rivers the Ganga and the Brahmaputra. The loss of cattle and human lives was great and the destruction of houses and other properties was extensive. But as compared to the suffering and loss during 1950 and 1954 floods they were insignificant. During later years the refugee settlements that had come up like mushrooms in these areas after the partition of Bengal were razed to the ground and human sufferings and loss of lives were untold. Some of the Tea Estates were severely damaged and numerous railway and road bridges destroyed. Many of the Tea Estates and towns were covered with coarse sands entailing permanent loss of their valuable properties.

Besides human encroachments into flood-plains, the drainage of the river channels have been deteriorating progressively. The two main rivers, the Bhagirathi-Hooghly and the Rupnarain, that carry the run-offs from the whole of the Gangetic West Bengal south of the Ganga and of the undulating hilly districts of Chotanagpur and Santhal Parganas, are losing their drainage capacities at alarming rates. The total extent of this drainage area is about 32,000 sq. miles with incidences of annual rainfall varying from about 100 inches near the sea coast to 50-55 inches in the hilly tracts of West Bengal and Bihar. In one rainstorm the magnitude of the precipitation can reach as high a value as 12 to 15 inches in the course of three, four or five days. Run-off ratios in the neighbourhood of 70-75% are frequently reached specially towards the end of the monsoon season, i.e. in the months of September-October. These heavy precipitations beating on the bare uplands of Bihar and West Bengal come down in torrents unobstructed by any vegetative cover and carry enormous quantities of debris, coarse sand, fine sand, silt and clay, into the flood-plains of West Bengal bordering on the two main drainage arteries of the State. This enormous volume of detritus deteriorates

drastically the drainage capacities of the two outfall rivers. This process of deterioration is accelerated by the total absence of any upland flow during greater part of the year and by the opposing action of the tidal impulses that visit the lower reaches of these outfall channels regularly all throughout the year. This enormous volume of detritus load that reduces so drastically the river capacities in the flood-plains and in turn increases the frequency and intensities of floodings by them, is the direct product of soil erosion that is taking place in the hilly districts of West Bengal, Chotanagpur and Santhal Parganas. Bad land management is at the root of all these troubles. This again poses a human problem. Retention Reservoirs may help but unless the land is properly managed and covered over with vegetation, sheet erosions and gully formations cannot be stopped and the root cause of floodings in the flood-plains will not be removed.

The correct solution of Flood Problem in West Bengal and for the matter of that in other similarly affected areas of India, depend on—

(1) Proper Land Management in the upper reaches of the rivers.

(2) Proper Human Settlements in the flood-plains.

Unless these are attended to seriously, construction of retention dams and raising of embankments will be only temporary palliatives that may prove in the long run more harmful than the disease. Admittedly the remedies suggested are much more difficult to give effect to than the engineering difficulties of the other measures, but it is to be recognised that without them no other devices can be completely successful. Under certain circumstances these devices can on the other hand be definitely harmful.

It is needless to cite more examples. In North Bengal, and for the matter of that in the whole stretch of the submontane tract of the Himalayas, bad land management has led to ruthless cutting away of trees and vegetative covers resulting in quick run-off and land slides along the whole mountain sides for miles and miles at a stretch. The enormous volume of debris that are dumped into the river beds and subsequently washed into the flood plains at the foot-hills have brought about disastrous floodings and sandings in the northern districts of East Punjab, Uttar Pradesh, Bihar, West Bengal and Assam. The indications are the same all over; the factors responsible are also the same. The people who have settled in these hilly tracts want fuel and land for cultivation. They must have these amenities of life and unless these are provided in a planned way, they will fell the trees, prepare clearings for cultivation and thereby lead the way to extensive land slides and consequent floodings in the plains. Proper and planned land management is what is required in these areas. Construction of retention dams is not the solution.

From the days of Miami Conservancy Board to the present day it is not a long cry. Yet the epoch-making experiments that were started in the beginning of the present century have demonstrated very clearly that multipurpose River Valley Projects cannot solve all flood problems unless improvements in the condition of the upper catchments and those of the lower flood plains are also included in the Project. These schemes will not yield immediate benefits but they hold the key to the success of the whole project and must be tackled successfully and in time.

As has been said before, proper land management in the catchment of a river valley and judicious land settlement in the lower flood plains are difficult of achievement because they involve human problems. Man's control over physical nature has been more successful than over human nature and it is very often that the latter gets the upper hand and upsets many of our nicely calculated projects. Floods have proved one such problem for us and unless we can solve it on the human plane, they will continue to be as great a menace to present day civilisation as in the early days of man's history.

INDIAN INSTITUTE OF SCIENCE, BANGALORE

CIVIL AND HYDRAULIC ENGINEERING SECTION

WILL HOLD A

SYMPOSIUM

ON

FOUNDATION ENGINEERING

ON

12th, 13th and 14th January 1961

B. M. Abbas
Commissioner, Water Development
East Pakistan Water & Power Development Authority

Water and Power Development in East Pakistan

EAST PAKISTAN CAME INTO BEING AS A PROVINCE OF the new State of Pakistan in August, 1947, comprising the eastern part of the former Bengal with the addition of a major part of the former district of Sylhet of Assam. The greater part of East Pakistan is a vast stretch of alluvial plain with hills only on the eastern and south-eastern border and is watered by a most remarkable network of rivers. The province has an area of 54,141 sq. miles and had a population of 42 million in 1951. Before Independence, this part of the undivided sub-continent of India was relegated to the backwaters and served only as a base for raw materials to feed the industry and commerce of Calcutta. It had no major industry. No work of irrigation or power development was initiated in these parts. Development has, therefore, to start from scratch.

Rivers

East Pakistan forms the major part of the huge delta of the Ganges-Brahmaputra river system. The two rivers meet within East Pakistan and combining with another big river the Meghna open out in a collosal estuary in the Bay of Bengal. The total discharge in the three rivers during the monsoon runs to about 5 million cusecs. During floods the Ganges and the Brahmaputra which originate in the Himalayan mountains bring down a vast quantity of silt to their mouths at the sea face where it is checked and redistributed by incoming tides of high range. A large number of subsidiary spill and drainage channels traverse the delta.

Topography

A characteristic feature of the topography is the innumerable low-pockets of various sizes and depths all over the province, the result of the deltaic action of rivers which raise their banks with silt deposit and then find out other channels to repeat the process. Some zones have been adversely affected by a major shift in the course of the big rivers. The spill channels of these areas have been cut off from the main rivers at their offtakes and receive flood water from the rivers only at high stages of flood. Deprived of the flood waters and their soil-enriching silt, the areas have deteriorated in soil fertility and general condition. This effect is noticeable specially in parts of Rajshahi, Pabna, Faridpur, Kushtia and Jessore districts.

Soils

The alluvial soils formed by silt deposit cover approximately 90% of East Pakistan. Only in the extreme north and in the Chittagong Hill Tracts there are old soil formations. In the north western part and in the middle of Dacca district, there are red soils, an alluvium of less recent origin than the other alluvia. The most fertile soil is the Ganges alluvium, found in the south-west of the province. One of its excellent properties is the high content of free lime. The Brahmaputra alluvium does not contain free lime and is, therefore, not so fertile as the Ganges soil. Part of the Brahmaputra soil is found in the Meghna basin. However, this basin now receives only Meghna water which does not contain much silt. The Teesta alluvium is found in the north-western districts. Its deposits are rather coarse and more permeable than other soils. For their light texture, these soils are excellent for crops like tobacco, potato and rabi crops. Marine soils are found in the Khulna region.

Climate

The climate, specially rainfall, influences the pattern of agriculture. There are three main seasons:—

1. Winter (November to February)—Mild and almost completely dry.
2. Warm Summer (March to May)—When violent thunderstorms called North-Westers occur and bring down one-fifth of the total annual rainfall.
3. Rainy season (June to October —Warm, rainy and humid.

Temperatures range from approximately 50° minimum in January to 95° maximum in April and May. The average annual rainfall is 80 to 100 inches. The minimum of 55 inches occurs in the south-western districts and the maximum of 150 to 200 inches occurs in the north-eastern part.

Agriculture

In the wet season, 70% of the flat lands is inundated by rain or river water. The only crop that can be grown on the inundated lands is rice. *Aus* is grown in the higher part where water will not be more than a foot high, transplanted *Aman* where the water depth will remain below 3 to 4 feet and broadcast Aman where the water-level will be higher.

In the dry season, only a small part of the land can be used for a second crop: in the high lands which become dry in September and October and can profit from high ground water table and some rainfall and in the lowest lands which never become completely dry. The average low lands remain unused for double cropping.

For the wet season lack of water can hardly be exactly to be a reason for low production. Yet, for Aus rice, drought is very often the cause for low yields and frequently total failure. Aus rice is broadcast mostly in April after some rainfall when the seeds can germinate. The young rice plants are very sensitive to drought and a week or two weeks' drought proves fatal to the crop. The earlier the paddy is sown the greater is the danger of crop failure by periods of drought. Late sowing is risky because after germination the young plants cannot stand submersion.

Too much water can also be fatal for transplanted Aman rice. During transplantation the water level has not risen more than a foot above the land. After transplantation there is a critical period during which the rice plant has to establish itself in its new environment and the root system has to develop. In this period the plant does not grow. The plants drown if there is a sudden rise in water level. This often happens.

The Aman is broadcast in March or April after some rainfall, when the soil is not yet submerged. When the floods come in June, the plants have enough vigour to follow the rise of water. But when the rise is too quick the plants drown. They can stand submersion for 3 days. As long as the water rises moderately, the plant growth keeps pace with it. When the water does not rise any more during a certain period, the rice starts to form ears. If water begins to rise again during the generative stage of the paddy, it can no longer grow and is exposed to drowning. So Aman rice can fail both as a result of early as well as late flooding. Rice growing in East Pakistan is, therefore, a gamble with nature.

Recurring high floods and droughts at critical periods affect crop production every year. The population is also growing at a rapid rate. East Pakistan has been unable to meet her requirements of food and has to import large quantities of foodgrain every year. The urgent need is, therefore, assured and adequate food production.

The floods, the tide and the silt pose a complex problem of unparalleled magnitude. East Pakistan has no control over the course of rivers as all the major rivers originate outside its border. Extensive dyking of rivers is possible but apart from their hydraulic effect on the river system, it would be prohibitive in cost and would involve a great danger in the event of dyke-breach. The different aspects of the problem are, however, being studied. One way to offset the losses in crops caused by floods is to accept the monsoon crops as risk crops and grow food crops during the winter when the conditions are under greater control. This would be possible through irrigation.

Land Use

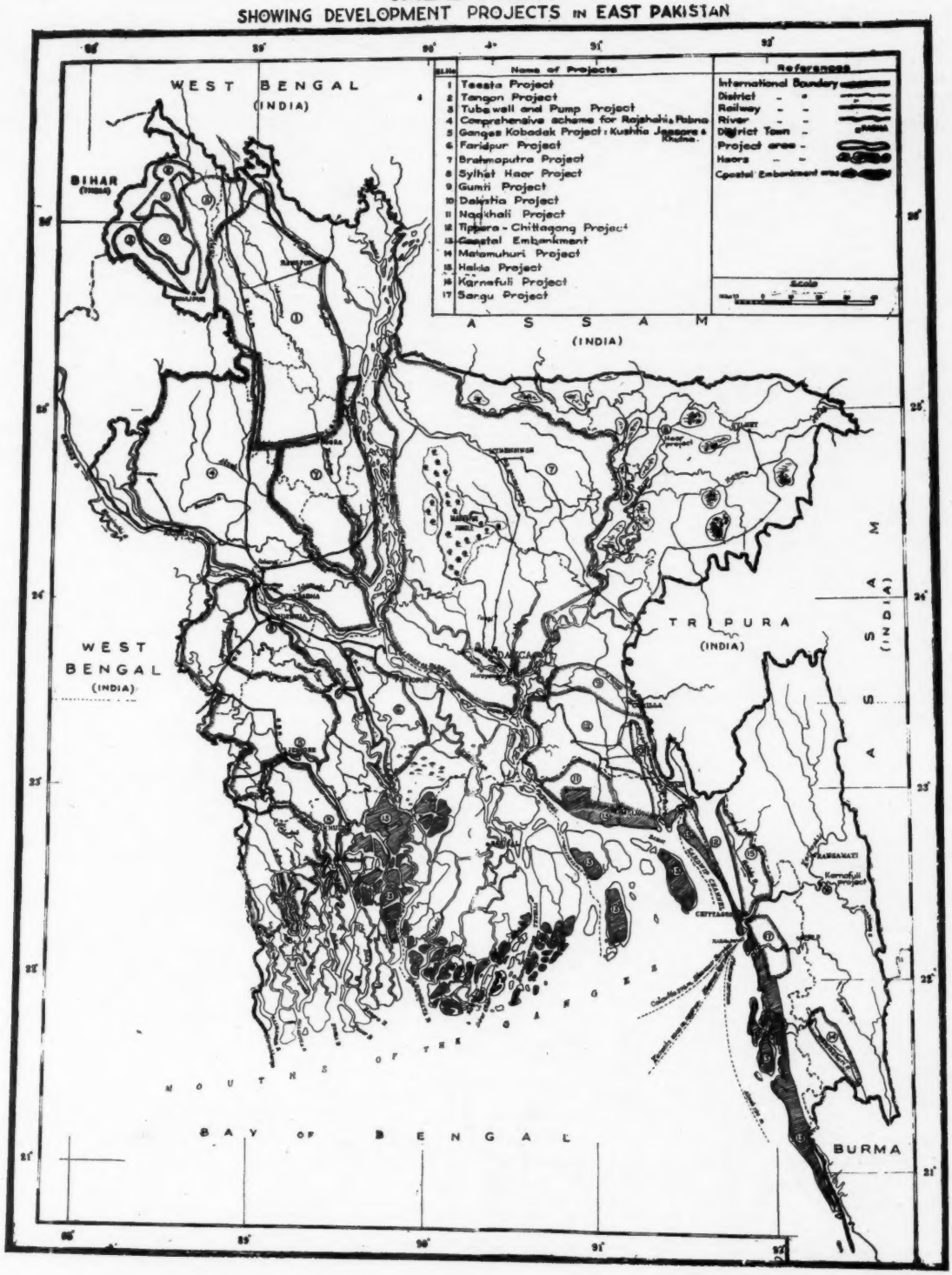
The total area of the province is about 34.5 million acres, of which nearly 15 per cent is under forests, about 63 per cent has been brought under cultivation, 10 per cent is not available for cultivation, while about 12 per cent is cultivable waste. Of the 63 per cent under cultivation annually, about 8 per cent remains current fallow, due to unfavourable climatic conditions and other factors e.g. want of cattle, finance. It is estimated that approximately 70 per cent of the total area of the province, i.e. about 25 million acres is capable of being utilised for agricultural purpose.

The density of population in these parts is one of the biggest in the world. Though the average is about 780, it is in many places over 1,500 and near the confluence of the Ganges and the Meghna, it is as high as 3,000 per sq. mile. In spite of the pressure of population, most of the cultivated area is cropped only during the wet season after which the moisture in the land is generally insufficient. The second crop area is about 7 million acres. Perennial irrigation could be provided for a major part of the cultivated land and the effective land area could be doubled through system of rotational cropping. It has been found from a study of crop yields under irrigated and dry farming conditions that the average yield under irrigation could be about 3 times the present average.

The scope of increasing the physical area under cultivation is limited as most of the arable land is already under cultivation. However, the *haor* areas in the districts of Mymensingh, Sylhet, Tippera and Dacca and the *beels* in the districts of Rajshahi Pabna, Faridpur and Barisal offer scope for reclamation. The tidal belt in the coastal zone which is subject to inundation by sea water can, if suitably protected by dykes, contribute substantially to increased food production.

INDEX MAP

SHOWING DEVELOPMENT PROJECTS IN EAST PAKISTAN



Creation of Authority

In order to develop the water and power resources of the province on a unified and comprehensive basis, the Government of East Pakistan set up in early 1959 a semi-autonomous body called the East Pakistan Water and Power Development Authority. The immediate problem that the Authority was faced with was the great lack in technical personnel, construction machinery and equipment and workshop facilities. To offset the shortage of engineers and in order to ensure proper and expeditious planning of projects, the Authority has obtained the services of firms of Consulting Engineers for general planning as well for specific projects. Engineers are being recruited from all available sources and the shortage in personnel is being further made up by science graduates and under-graduates who are being trained for various jobs, e.g. statistics, surveying, hydrological observations, soil studies, etc. A Hydrology Directorate has been created and widescale hydrological observations of rivers are being carried out to establish the basic data for projects. The Hydraulic Research Laboratory is being developed to carry out the necessary model studies of behaviour of rivers and research on tides. Repair facilities and spare parts for the construction machinery and equipment are being provided to keep them in proper maintenance and operation.

Programme

The programme of East Pakistan WAPDA for increased food production has the following objectives:—

(i) Provision of irrigation facilities by the maximum possible utilisation of surface and ground flows.

(ii) Improvement of drainage of land and reducing flood damage.

(iii) Protection of the tidal zone against intrusion of sea water and its development through improved irrigation and drainage.

(iv) Reclaiming low beels and haor areas for agricultural production and their development for irrigation.

Irrigation

The irrigation projects will make use of surface water from rivers and streams either by gravity flow or lift pumping and of sub-surface water by means of tubewells. Irrigation will supplement the rainfall to insure the summer crops against failure and will provide water in the dry season for growing a second and a third crop. The major irrigation projects under execution or planning are:—

1. Teesta Barrage Project.
2. Tangon Irrigation Project.
3. Tube-well Irrigation and Pumping Project.
4. Comprehensive scheme for Rajshahi and Pabna districts.
5. Ganges-Kobadak Project.
6. Garai Irrigation Project.
7. Brahmaputra Project.
8. Haor Reclamation Project.
9. Tippera-Chittagong Multi-purpose Project.

The above projects will irrigate a total area of roughly 12 million acres. The Teesta, the Tube-well and the Ganges-Kobadak Projects are under execution. The others are in investigation or preparation stage.

Schemes Zone-wise

The several zones of the province present different topography and problems and the projects have to be planned taking into consideration the peculiar features of each zone.

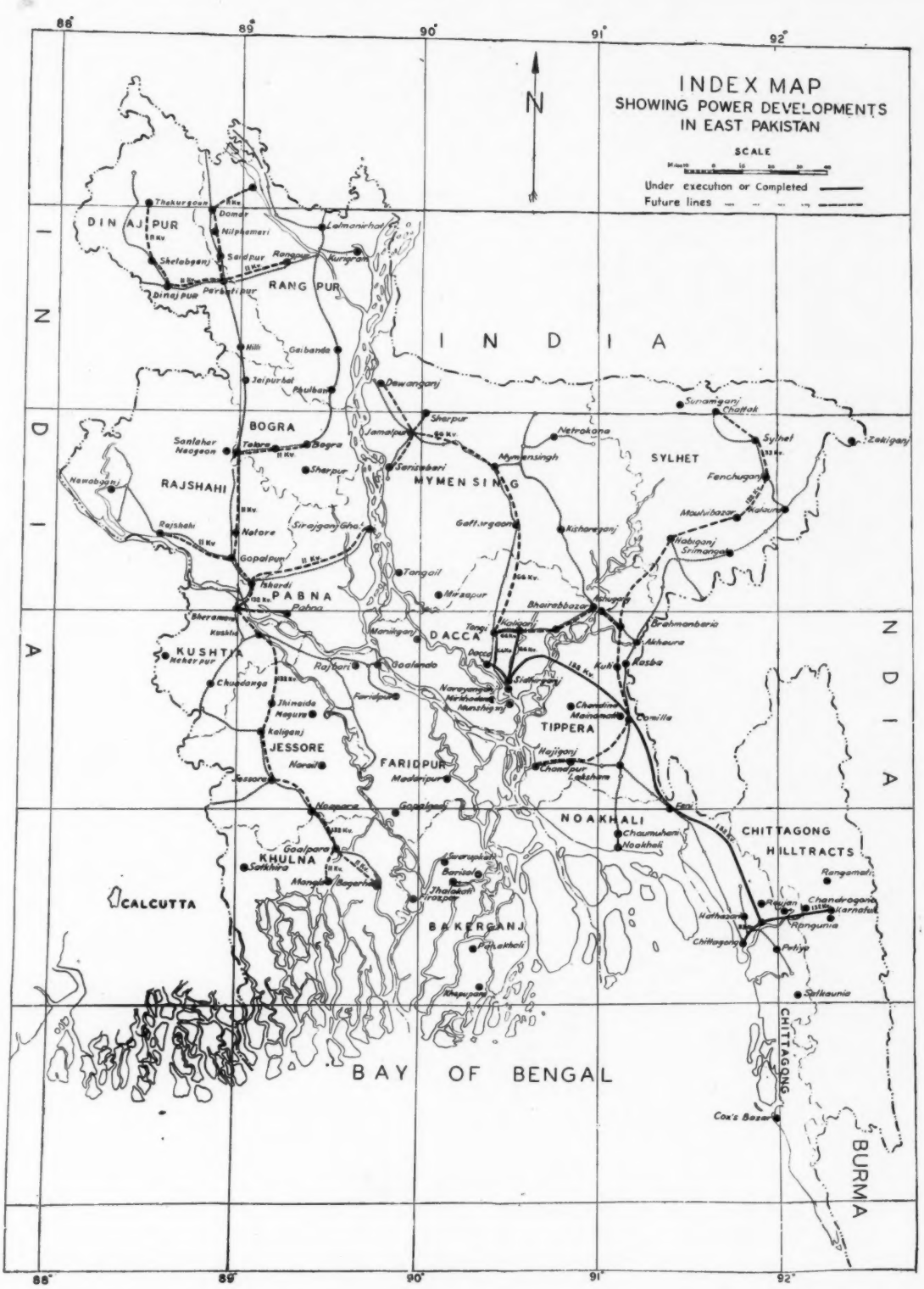
North-Western Zone :

The *North-Western Zone* of the province is comparatively high and dry. This area is served by the waters of the Teesta and other streams like Tangon, Korotoya, Punarbhata, etc.The major project in this region is the *Teesta Project* which provides for a barrage across the Teesta to irrigate about 1.35 million acres of land in the districts of Dinajpur, Rangpur and Bogra. The *Tangon Irrigation Project* provides for barrages across the Tangon and the Korotoya rivers to irrigate 300,000 acres of land in the Thakurgaon Sub-division of Dinajpur district. Other smaller schemes are proposed for utilising the water from the many streams flowing in this zone by low lift pumping. Investigations have been started for a *Comprehensive Scheme* for irrigation, drainage and flood protection of the area comprising the *Rajshahi and Pabna districts.*

Ground water development and tube-well irrigation is for the present planned for the North-Western part of the province which lies outside the command of the Teesta Project and other gravity or lift irrigation projects. About 560,000 acres of land may be irrigated by means of tube-wells. The immediate programme is to sink 300 tube-wells in Thakurgaon area of Dinajpur district to irrigate about 100,000 acres of land.

South-Western Zone :

The *South-Western Zone* of East Pakistan will be served by the Ganges-Kobadak Project and the Garai Irrigation Project. The *Ganges-Kobadak Project* will utilise the Ganges water to irrigate an area of 2 million acres in the districts of Kushtia, Jessore and Khulna. Supply of water to the Kushtia district and a part of the Jessore district will be by pumping from the Ganges. The lower area including a part of the Khulna district will be served by a gravity canal tak-


INDEX MAP
SHOWING POWER DEVELOPMENTS
IN EAST PAKISTAN
SCALE
Under execution or Completed
Future lines
N
88°
89°
90°
91°
92°
INDIA
INDIA
INDIA
DIN AJ PUR
RANG PUR
BOGRA
RAJSHAHI
PABNA
KUSHTA
JESSORE
KHULNA
MYMEN SING
SYLHET
DACCA
FARIDPUR
TIPPERA
NOAKHALI
CHITTAGONG
HILLTRACTS
BAKERGANJ
CALCUTTA
BAY OF BENGAL
BURMA
Thakurgaon
Domar
Nilphamari
Lalmonirhat
Saidpur
Rangpur
Kurigram
Shelabganj
Dinaj pur
Parbatipur
Gaibanda
Jaipurhat
Phulbari
Dewanganj
Sharpur
Jamalpur
Netrokona
Sunamganj
Chattak
Sylhet
Zakiganj
Fenchuganj
Maulvibazar
Kulaura
Habiganj
Srimangal
Kishoreganj
Gafforgaon
Sherpur
Jamalpur
Sirajganj
Natore
Rajshahi
Nawabganj
Gopalpur
Ishardi
Tangail
Mirzapur
Pabna
Bhairabbazar
Shuganj
Brahmanbaria
Akhaura
Kushtia
Meherpur
Rajbari
Goalando
Dacca
Kushba
Chuadanga
Faridpur
Narayanganj
Munshiganj
Chandina
Comilla
Jhinaida
Magura
Kaliganj
Narail
Hajiganj
Chandpur
Lakshma
Jessore
Madaripur
Noapara
Gopalganj
Feni
Chaumuhani
Noakhali
Goalpara
Satkhira
Mongla
Bagerhat
Barisal
Jhalakati
Patuakhali
Rangamati
Raojan
Chandraghona
Karnafuli
Rangunia
Hathazari
Chittagong
Puhiya
Satkaunia
Khepupara
Cox's Bazar

ing off from the Ganges. The Khulna unit of the Project includes polders to protect the area from incursion of sea water. The *Garai Irrigation Project* will supply irrigation water to 1.8 million acres of land in the districts of Faridpur, Barisal and part of Khulna district. The Barisal and Khulna (Bagerhat) region will also have polders to protect the lands from sea water.

North-Eastern Zone :

The *North-Eastern part* of the province will be fed with water from the Brahmaputra through its old course flowing via Mymensingh. The *Brahmaputra Project* provides for canalising the old Brahmaputra and its various spill channels and introduction of Brahmaputra water through a regulator at the offtake for irrigating 1.8 million acres of land in the districts of Mymensingh and Dacca. The Project provides also for flood protection by embankments to protect the area from flood water from the Brahmaputra and other streams coming down the Garo Hills. For the low haor areas in Mymensingh, Sylhet, Comilla and Dacca districts, about 1.75 million acres, projects are being planned to provide water during the dry season for winter crops. Feasibility of protecting these lands from floods by means of dykes and making them fit for summer cultivation by provision of drainage pumping is being investigated. The Meghna depression in the lower Surma Valley is a special problem. It becomes a big inland sea during the monsoon and dries up during the winter. A study of the area is being carried out.

South-Eastern Zone :

For the *South-eastern part* of East Pakistan, a project named *"Tippera-Chittagong Multi-purpose Project"* is under preparation for irrigating about 1 milion acres of land lying in the districts of Tippera, Noakhali and Chittagong with fresh water from the Meghna. This project provides for an irrigation-cum-navigation canal from Chandpur to Chittagong via Laksham and Feni. The water will be raised at Laksham to allow gravity flow in the reach of the canal leading to Chittagong. The canal in this portion will have tidal embankment to protect the lands from sea water. Irrigation Projects are also being planned for irrigating the *Halda, Mathamuhuri* and *Sangu* basins of Chittagong district.

Research and Extension Service

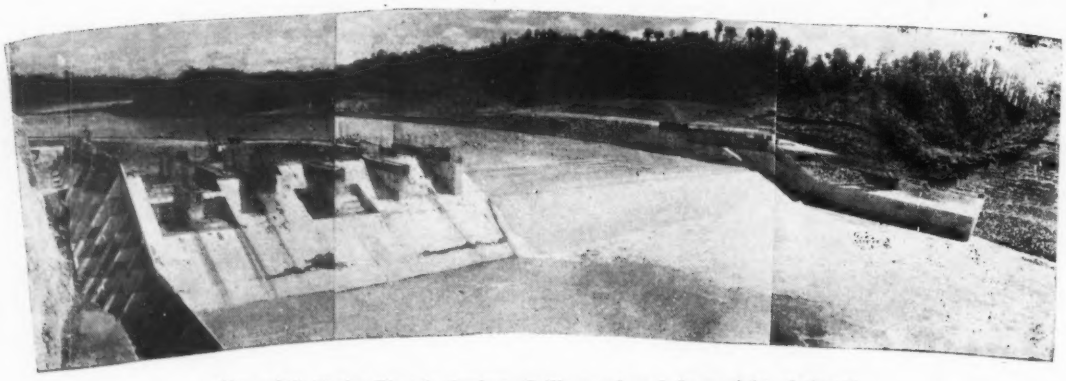
Introduction of planned irrigation has to be complemented with agricultural research and extension service. Detailed soil survey and studies on agronomy, soil fertility. and farm management have been carried out in the Ganges-Kobadak area and are being continued. Similar surveys are in progress in Teesta area. Research work on soil is being carried out in WAPDA's Central Soils Laboratory along with experiments in the field. Pilot and demonstration farms have been set up in Kushtia. Khulna and Rangpur districts. In the pilot farms, studies are going on to determine the best crops and varieties for double and multiple cropping pattern and suitable cultivation practices under irrigated condition and in the demonstration farms, water is being supplied to fields to acquaint the cultivators with the use of irrigation water and best cropping method. Extension services are now being started in Kushtia area where irrigation water will be delivered to the fields in the winter of 1960-61.

Small Schemes

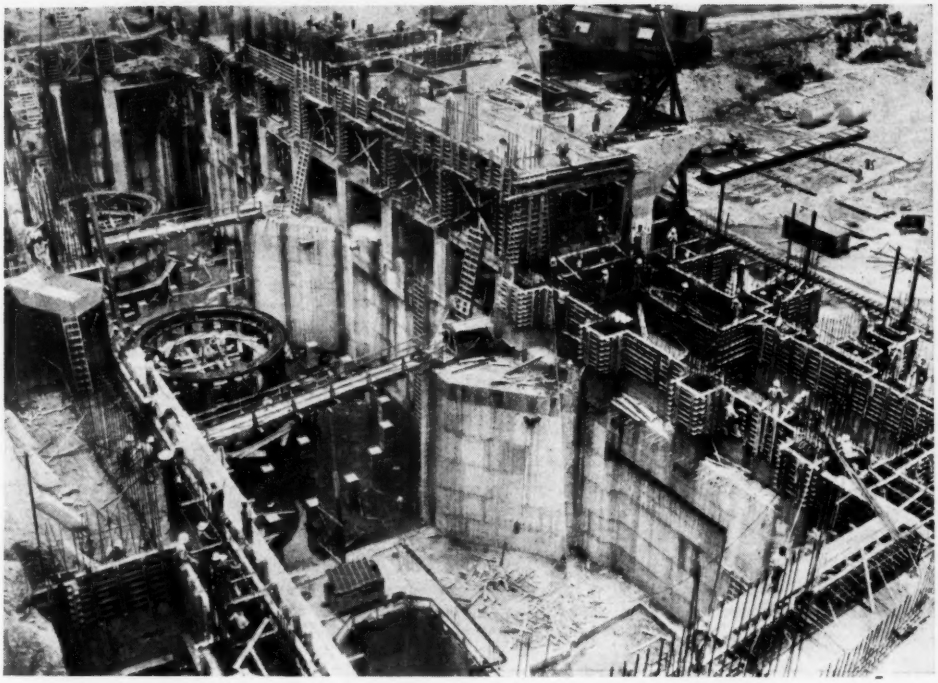
For the improvement of drainage of low pockets and protection of lands from flood damage, a large number of smaller drainage and embankment schemes has been taken up by the WAPDA in different parts of the province. These schemes are expected to benefit about 300,000 acres of land during the next five years.

Coastal Embankments

A scheme of coastal embankment has been taken up in the districts of Khulna, Jessore, Barisal, Noakhali



Karnafuli Hydro-Electric Project. Spillway viewed from right abutment.



Karnafuli Hydro-Electric Project. General view of the Powerhouse from right side upstream.

and Chittagong to protect about 1.6 million acres of land in these districts from the incursion of sea water. The total length of embankments to be constructed or remodelled is 3,200 miles. The work will be completed in 5 years. This will ensure one rice crop in these areas. For growing a second rice crop, irrigation facilities are planned for a later stage.

Second Five-Year Plan

Pakistan's Second Five-Year Plan covering the periods 1960-61 to 1964 65 envisages for East Pakistan an outlay of 152 crores of rupees on water and power development, 123 crores in the water sector (including hydro-electricity) and 29 crores in the power sector. The plan of water development provides for necessary surveys and research, completion of the Karnafuli hydro-electric project with its 3rd unit, Kushtia and Jessore units of Ganges-Kobadak Project, tidal embankments and tube-well project. The Teesta Barrage Project and the Khulna unit of Ganges-Kobadak Project will be under execution in the plan period and a beginning will be made on a comprehensive scheme for the Rajshahi and Pabna districts, the Brahmaputra Project, Tippera-Chittagong Project, reclamation of haor areas and other projects. The physical targets set for the Second 5-Year Plan period are generation of 120,000 kW. of hydro-power, irrigation facilities for 1 million acres of land, protection of 1.6 million acres from tidal inundation and reclamation of 300,000 acres of low lands for agriculture.

Power

At the time of Independence, East Pakistan had 32 generating stations, all thermal, with a capacity of 21,000 kW. in the whole of the province. Today the total installed generating capacity, all thermal, is about 200,000 kW., half of which is controlled and operated by East Pakistan WAPDA. The balance of the generators are installed in small industrial and commercial endeavours scattered throughout the province. A power survey has recently been carried out to assess the expected load growth and demands by consumers in the future. The present day demand is estimated at roughly 100,000 kW. The load survey indicates that the demand in 5 years would rise to 260,000 kW. and by 1970, 400,000 kW. The bulk of this expected demand will be in the sphere of expanding industries, new manufacturing firms, new developments and numerous pump-irrigation and land reclamation projects. East Pakistan WAPDA, is therefore, going ahead with construction and planning of new power projects.

The scope of hydro-electric generation in East Pakistan is limited in view of its flat configuration. However, the Chittagong Hill Tracts offer scope of development from the rivers Karnafuli and Sangu. A dam is now under construction across the Karna-

fuli river at Kapati for generation of hydro-power. This power plant will have an initial installation of two 40,000 kW. generator units with a provision for a 3rd 40,000 unit. The Karnafuli Hydro-electric Project is expected to go into operation in 1961-62 when it will increase the power capacity of East Pakistan by 40%. A natural hydro-tlectric potential in the Chittagong Hill Tracts on the Sangu river is now under investigation. The Sangu Project is expected to provide about 20,000 kW. of hydro-power. The steam generating plant of 8,500 kW set up at Bheramara in connection with the Ganges-Kobadak Irrigation Project will provide surplus power for domestic consumption. The Teesta Barrage Project, the Bramaputra Project and the Khulna Project are expected to generate substantial amounts of hydro-power from canal falls.

Besides augmenting the existing thermal stations at Siddhiherganj (Dacca), Goalpara (Khulna) and Chittagong and connecting them by grids between Kaptai and Chittagong and between Bheramara and Goalpara, plans are underway to grid Comilla with Sylhet where a gas power station has been put up in connection with the fertiliser factory at Fenchuganj. The discovery of natural gas in Sylhet offers good opportunities for meeting the increasing need for power generation in East Pakistan. The natural gas deposits at Rashidpur will be utilised in new thermal generating plants planned for in the future and other thermal plants will be located at new gas deposits as these are developed.

Peat has been discovered in Faridpur and Khulna district and is being developed. Investigations are also being carried out to develop coalfields in Bogra. This will provide a much needed fuel for thermal generating plants.

In order that power from all power stations are made available to all corners of the province, network of high tension and medium tension transmission lines will be constructed. Extensive distribution system will be provided at all load centres to provide consumers with electric power at their demand. Most of these plans are being initiated in the Second Five-Year Plan period and their completion can be expected in the Third-plan period.

The East Pakistan Water ond Power Development Authority intends to bring electric power within the reach of every citizen of East Pakistan, firm and industry in need of electricity as the growth and future of the country will depend to a large extent on extensive application of electrical energy to all national endeavours.

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Harza Engineering Company

Design of Karadj Hydro-electric Project

THE KARADJ DAM IS LOCATED ON THE KARADJ River about 40 kilometers (25 miles) from the city of Terhan, Iran. The project will be owned and operated by the Karadj Dam Authority, which is a division of the Plan Organization of the Government of Iran. The project is the culmination of many years of effort to assure an adequate and reliable supply of municipal and industrial water for the rapidly growing capital city of Tehran. A secondary benefit of the project is hydroelectric peaking capacity to augment the electrical power resources of the Tehran area.

The project is of major proportions and has several features of special interest. At the time of completion, the double-curvature arch dam will be the tenth highest in the world and the highest dam in the entire Middle East area. The dam rises 584 feet about the lowest point in the foundation. The gated chute spillway on the right abutment is designed to pass a 52,000 cfs. design flood. The flow is contained by training walls down to the terminal deflector, at this point, 50 feet above the river, the flow is turned away from the abutment and lands in the river well downstream of the dam and powerhouse.

The above-ground powerhouse provides space for three generating unit of 111,000 kva total capacity. Two units will be installed immediately, and the third unit is scheduled for installation at a later date as required by the load growth.

History of the Project

For many years, Tehran was a small village in rural Iran, relatively unimportant when compared with the ancient centers of commerce and culture, Isfahan, Shiraz, and Tabris. The energy requirements of such a village were nil and the water supply was adequately handled by a series of long, hand-excavated tunnels called "quanats." These tunnels occasionally extended for distances of ten miles or more under the alluvial soil to reach an aquifer in the foothills. Water flows through these tunnels by gravity to a point on the plain such as Tehran or to agricultural areas for irrigation.

In the 19th century, the capital of Iran was moved to Tehran and a rapid and continuing growth of population commenced. Tehran is now one of the largest cities in the world not located on a body of water or a river. The local annual rainfall of only ten inches was insufficient to support the needs of either city water supply or irrigation needs, and, therefore, as early as 1937, consideration was given to the development of a storage dam at Karadj. The earliest studies of this site were made then under the direction of German engineers.

After World War II, the increased growth of the city led to a critical situation in water supply and electrical energy. Studies of the Karadj damsite were resumed and various plans were prepared. One study was made by the French firm of Entreprise Metropolitaine et Coloniale in collaboration with Professor Albert Caquot and another, a project set forth by the USBR study team as recorded in a two-volume report on the Karadj Dam Project dated 1954. Both these suggested developments called for a high arch dam together with a hydroelectric power plant located on the diorite sill formation, which forms the site of the present Karadj Dam. Late in 1955, a modern water treatment plant and municipal water distribution system went into operation. Steps were undertaken to implement the Karadj Project as a reliable source of water and Harza Engineering Company International was engaged to design and supervise the construction of the project, with Morrison-Knudsen Company International as the constructors.

The project will be financed with funds available from oil royalties, and will thus utilize a depleting energy source to construct a permanent water conservation and energy resource in the form of a 115.6 millions cubic meter (94,000 acre-feet) annual stor-

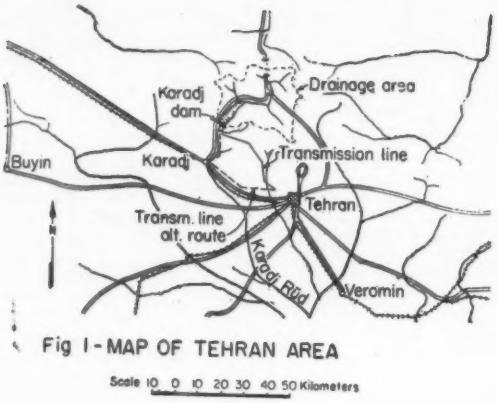

Fig 1-MAP OF TEHRAN AREA

age reservoir and a hydroelectric capacity of 149 million kilowatt hours per year.

Purpose of Project

The primary purpose of the project is to provide a dependable industrial and domestic water supply for the rapidly growing city of Tehran. The development of water supply at Karadj will also provide some benefits to the flood control of the area. It was found economical in connection with the development of water supply to install a hydroelectric plant to provide peaking capability for the Tehran electrical system.

The total annual charges using an assumed interest rate of 4½ percent are estimated to be equivalent to $3.7 million. Just over 50 percent of this will be recovered from electric revenues and the remainder will be charged against water supply. When fully utilized, this will provide water at one cent per cubic meter and this is deemed to be reasonable under the circumstances. Benefits to result from irrigation water supply and flood control have not been estimated for the purpose of justifying the project. In arriving at the annual charges above, the project equipment is assumed to be fully depreciated over a 30-year period, the power plant structure over a 50-year period, and the main dam and spillway over a 100-year period.

Selection of Type of Dam

During the course of the studies made of the Karadj Project, consideration was given to various heights and structural types of dam. These studies soon centred around reservoir elevations between 1750 and 1760 meters and an arch dam or rockfill dam type of structure. A report submitted by the Harza Engineering Company International on August 15, 1956 made a final comparison of arch dam and rockfill dam types for a range from El. 1735 to El. 1780 meters. An international board of consultants consisting of Jean Bellier (France), Robert Fitt (England), and I. C. Steele (M. ASCE, U.S.A.) was assembled to study the report and to recommend a final height and type of dam. The Board agreed with the recommendation set forth in the above-mentioned report, i.e., a double-curvature arch dam with crest at El. 1768 meters.

The topography of the site was almost ideally suited to an arch type dam. On the other hand, the steep canyon walls presented a problem in the design of the core of a rockfill dam of this magnitude that would adequately provide a permanent seal at the contact with the abutments. In addition, there was no proximate source of core material, the nearest source of sufficient volume being about 20 miles downstream. The economic studies indicated that there was no advantage in the rockfill dam layout.

Description of Project

The Karadj Project (Fig. 2) consists of the main arch dam, a gated concrete chute spillway, reservoir outlet works, power plant, transmission lines, a downstream reregulating dam, and nine miles of relocated highway.

From the deepest point in the excavation to the roadway, the dam will be 178 meters high, and the arc length measured at the roadway is 390 metres. The main dam (Fig. 3) is of the double-curvature type, with horizontal circular arches of approximately constant central angles. The radii of the arch centerlines vary from a minimum of 74 meters at elevation 1612 meters to a maximum of 201 feet at elevation 1768 meters, the roadway level. Arch thickness is 38 meters at elevation 1612 meters varying to 7.85 meters at the roadway.

The dam is analysed as a symmetrical structure with the base at elevation 1600 meters. Below this elevation, and on the right abutment, in the lower portion, plugs of massive concrete are constructed. These plugs are assumed to function as foundation rock, and are not analysed as a portion of the arch structure.

The dam was initially proportioned and shaped to fit the limited area of sound foundation and abutment rock that exists in the canyon. This structure was then analysed by the crown cantilever method to determine the general magnitude of stresses and to find if any major revisions were necessary. After minor adjustments, the stress analyses were continued. The analyses of the arch dam confirmed that the double-curvature shape permits very efficient structural utilization of the concrete in the main dam. With careful planning of construction operations such as schedule of concrete pouring, joint spacing, cooling and contraction joint grouting, the double-curvature design provides substantial savings in concrete volume as compared to other arch dam shapes and contains approximately 60 percent less concrete than a gravity dam type for the same site.

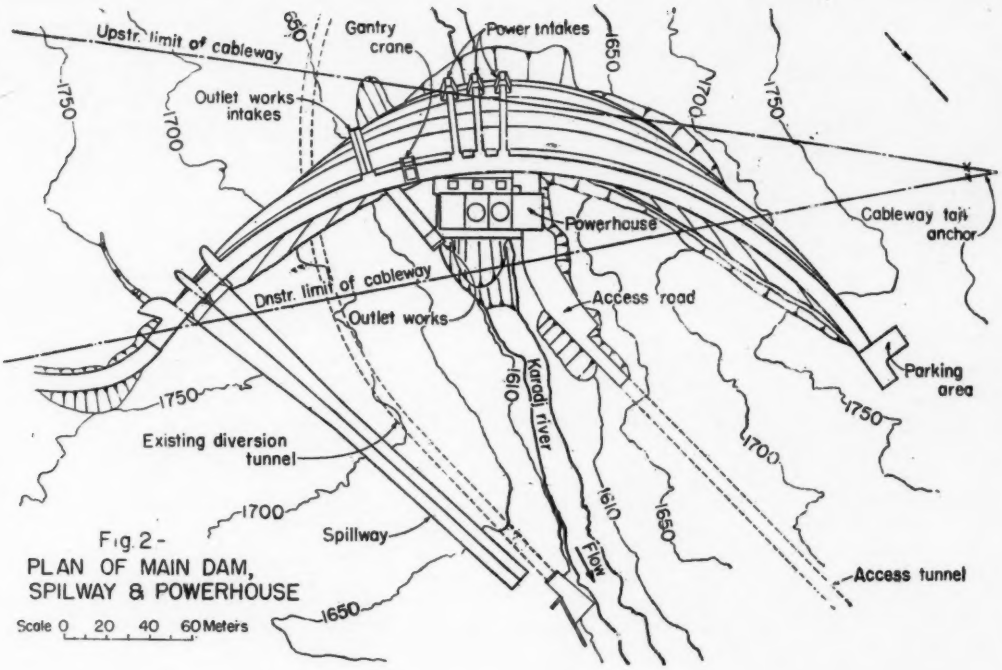

Fig. 2 - PLAN OF MAIN DAM, SPILWAY & POWERHOUSE

The next analyses made were the three and five cantilever analyses with radial adjustments. The computed stresses were within the range of allowable stresses, i.e., 150 psi tension and 1000 psi compression.

The following step in the arch dam design was to arrange for a complete structural model test program. The laboratory selected to carry out this program was Electricite de France model laboratory located at Chateau near Paris. The model studies and later the electronic computer program of the trial load type was administrated by the Campagnie Francaise d'Entreprise of Paris and directly supervised by engineers of the Harza Engineering Company Interntional. The combination of the structural tests with electric strain gauges on a series of plaster models together with the algebraic trial load analysis performed with the IBM-704 electronic computer served to confirm the suitability of the original dam structure layout, shape, and outline. Further, certain minor modifications to dam shape were suggested from the results of the testing program.

The model studies also answered two economically important design questions. First, thrust blocks would not be necessary on either abutment and secondly, the opening in the arch dam to provide for the spillway crest piers and gates did not materially affect the stresses in the dam nor the abutment loads and, therefore, a thrust beam would not be required across the top of this opening.

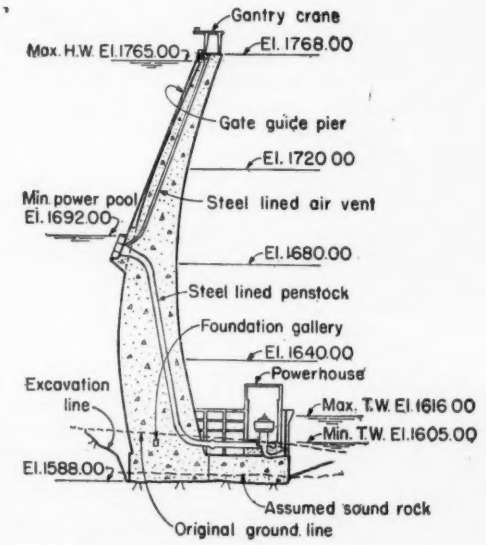

Fig. 3 - SECTION OF MAIN DAM

The model study program was planned to include tests that would incorporate the effect of the differential in the modulus of elasticity of the foundation rock relative to the arch dam concrete. However, the field in-situ rock modulus tests performed in galle-

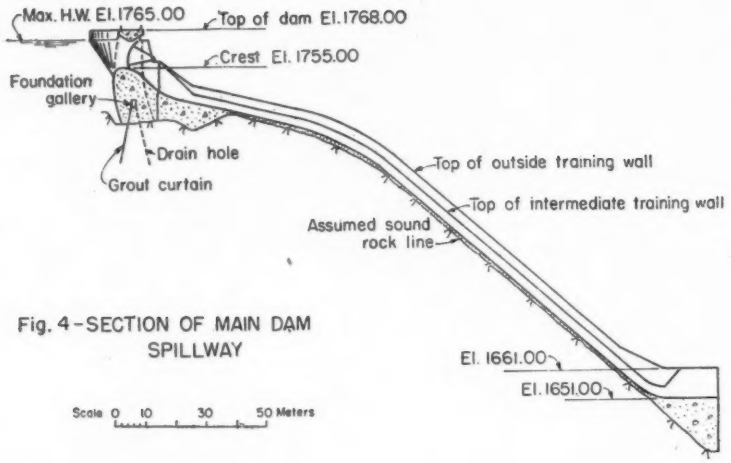

Fig. 4 - SECTION OF MAIN DAM SPILLWAY

ries in the foundation revealed that the foundation modulus of elasticity was quite close to that of the concrete. Foundation modulii measurements ranged generally from 2 to 2.5 million psi, while the value for main dam concrete is three million psi. Therefore, the above mentioned tests were not required and the material used to construct both the model of the dam and foundation was homogeneous plaster. (Fig. 8).

The arch dam concrete will be cooled in two stages by circulating water through embedded pipes. The first stage cooling will reduce the temperature rise developed by the heat of hydration. The second stage cooling will reduce the temperature of the mass concrete about 5°F below the average mean temperature of 54°F and will be accomplished prior to grouting the contraction joints of the dam. Either stage of cooling may utilize river water without artificial refrigeration. However, for occasions when the river water is too warm or when more rigid control of cooling water temperatures is required, a 800-ton refrigerating plant is provided. The second stage cooling operation will be carried out under closed system circulation to reduce the head required for the pumps and also reduce the volume of water treated for removal of silt or suspended solids.

The mass concrete for the arch dam is designed to develop 4,000 psi at one year. This concrete strength has been obtained in a mix with a cement content of 3½ bags per cubic yard. This content may be reduced near the crest of the dam where stresses are lower. Also additional experience as concreting operations progress may permit a reduction in cement content if actual strengths exceed the design requirements.

Instrumentation :

The program of instrumentation of the main dam includes the locating during construction of 161 thermometers, 58 jointmeters, 536 strainmeters, 16

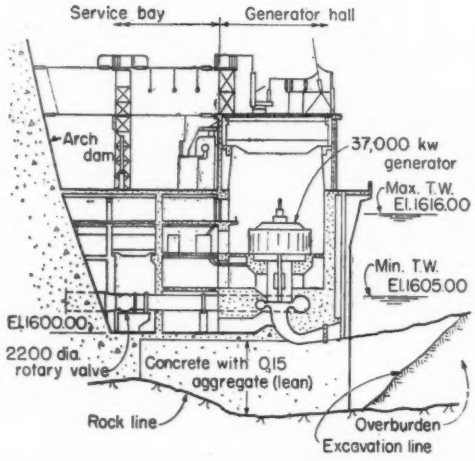

Fig 5 - SECTION OF POWERHOUSE

foundation deformation meters, and 21 embedded targets on the downstream face of the dam. A recording and analysis program is planned to provide a correlation between the prototype function and the model tests and trial load type analyses.

The foundation of the dam is a massive diorite sill. The presence of joints and fractures requires a careful grouting program to assure that the rock will act as a homogeneous mass. To assist in this program, and to permit grouting to be done without interference with the schedule of concrete placement, a drainage and grouting gallery is provided near the foundation throughout the length of the dam.

Two basic considerations were given to the arch dam underdrainage system. First, the uplift pressures are of minor significance to the design of arch dam

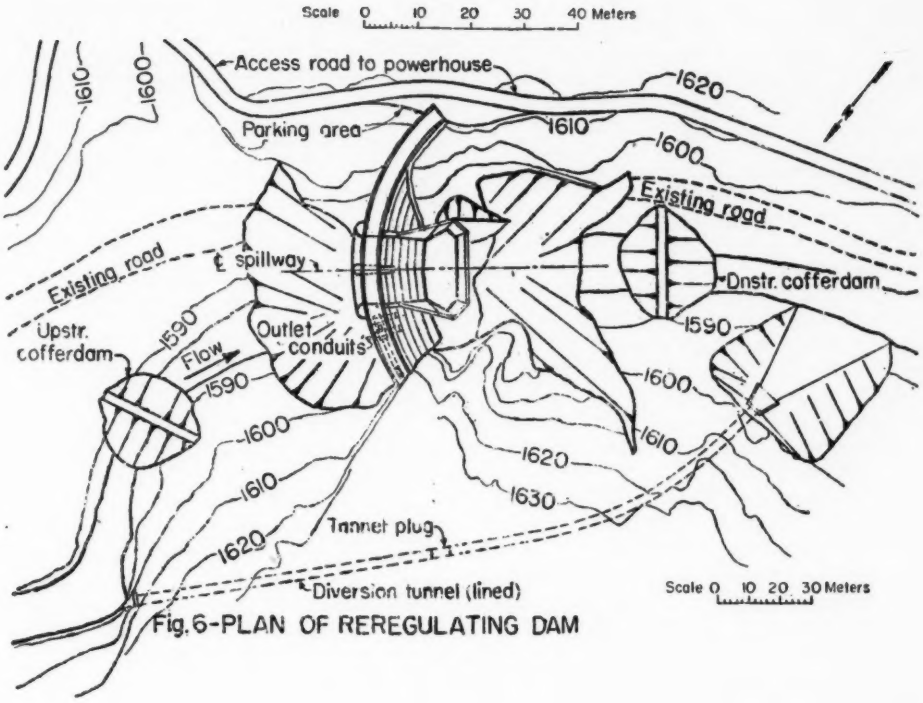

Fig. 6-PLAN OF REREGULATING DAM

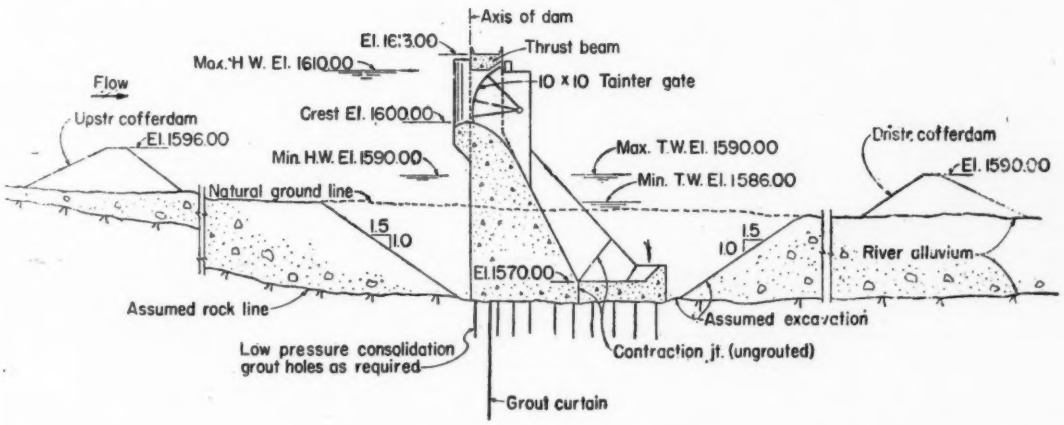

Fig. 7 - SECTION OF REREGULATING DAM

Fig. 8. Model of Karadj Dam in plaster for structural loading tests.

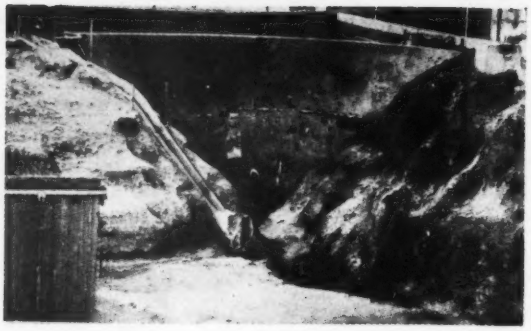

Fig. 9(a). Hydraulic Model of Spillway.

as compared to gravity type dam. Secondly, in the vicinity of the powerhouse relief of uplift pressure by adequate provision of drain holes and foundation drains was desirable to insure the stability of powerhouse. Uplift pressures were assumed to act over 100 percent of area of section with pressure diminishing on a straight line variation from headwater to atmosphere or tailwater. One drain hole for each block of the arch dam was provided to check the effectiveness of the seepage cut-off grout curtain. In the blocks immediately upstream of the powerhouse drain holes were spaced ten feet on centers to intercept all seepage and relieve uplift pressures. Drainage of the foundation will be through the gallery.

Main Spillway

The spillway is located on the right abutment (Figs. 9 and 10). Control is by two 32.8 feet tainter gates with the discharge carried in a chute. At a point well downstream of the dam and powerhouse floods will be discharged into the river by a terminal deflector structure at the end of the chute.

The gates will be operated normally by electrically driven hoists equipped for either simultaneous or individual operation. Local control at the spillway hoists, and alternative remote control from the powerhouse are provided. In case of power failure, the gates may be operated by manual driven connection at the hoists.

Hoists are located on the piers downstream from the roadway. The chain from the hoist drum is connected to the downstream side of the gate for ease of inspection and maintenance.

Hydraulic model tests were carried out by the University of Toulouse to determine the optimum approach shape, chute cross-section, chute transitions and superelevations, and to satisfy discharge conditions below the end of the chute (Fig. 9a).

Two phases of the hydraulic model work were unusual. Due to the profile of the foundation, water in the chute reached a high velocity at a point upstream from the transition section. This required special study to reduce the height of the standing waves by carefully determining the curvature of the transition and by superelevation of the chute floor in this area.

Due to flow characteristics of the river, in some years the spillway may operate frequently and under varying flows. To reduce the use of the river outlet valves the spillway will be used to waste all discharges above 30 cubic meters per second. Thus it was necessary to design a terminal deflector which would operate through a wide range of flows and discharge the water out into the river to prevent erosion immediately below the structure. After many trials in the model a shape was found which would operate under low flows, but which would not "clog-up" under high flows (Fig. 9b).

The foundation rock is very sound, but due to the joint system of the mass the surface is quite irregular after excavation. Seamy or jointed rock will be grouted prior to placing concrete. Low spots or areas will be filled with dental concrete to form a rough foundation grade; then anchor bars will be drilled and grouted into rock in certain areas. Drains will be formed on this rough surface to prevent uplift from raising the slab should dynamic pressure develop due to the high velocity flow.

The slab and walls will be reinforced, with special

Fig. 9(b). View of spillway model during tests.

Fig. 10. View looking upstream showing exposed rock foundation for chute spillway.

care taken in the design of shrinkage reinforcement. A minimum number of joints are used and those are provided with water stops and under drains.

During construction care will be taken in the interior surface finish of the chute and at joints to reduce erosion and cavitation.

A center wall throughout the length of the structure is provided to control the higher flows when the two gates will be operated simultaneously, and during low flows will permit either gate to be operated separately. This also has the advantage, in case of damage to the chute, that repairs may be made on one side while the other is available for passing lower discharges.

Outlet Works

Outlet works were provided through the right side of the dam to permit controlled release from the reservoir for downstream use in case of emergency. The capacity of each of the two outlets is sufficient to pass the required flow at all reservoir levels. These outlets also control the river flow during critical periods of reservoir filling during construction, prior to powerhouse completion.

Two outlets are provided. These consist of gated intakes, with trashrack structures, steel lined conduits 130 cm in diameter through the dam, with hollow jet dispersion type regulating valves, 76 cm in diameter at the outlet end.

The intake gate will be of the wheeled type for emergency closure operated by a fixed hoist near roadway level. Normally this gate will be in position over the intake and the conduit will be dry. Filling of the conduit for operation may be accomplished either through the cross connection with the penstocks. Air vents are provided downstream from the gate.

The centerlines of the intakes are at elevation 1660 meters which is 5 meters above the maximum level of sediment deposits expected after 100 years.

The regulating valve structure is located to the right of and is monolithic with the powerhouse. Discharge of the valves is at an angle to the tranverse centerline of the powerhouse and is directed downstream into a bend in the river.

For architectural appearance the downstream edge of the valve structure is on the same line as the draft tube deck. The roof of the valve structure will be at the same level as the draft tube deck, with valves and controls located below. Maintenance will be by means of removable hatch in the draft tube deck.

Powerhouse

The powerhouse is of the convential indoor type located just downstream of the dam. Space for three units is provided; two are to be installed initially.

The turbines are vertical shaft, Francis type, rated 49,700 horsepower at full gate and 456 feet net head, 300 revolutions per minute. The spiral cases are of welded steel.

The generators are of the umbrella type, rated at

Fig. 11. General view of excavation of left abutment

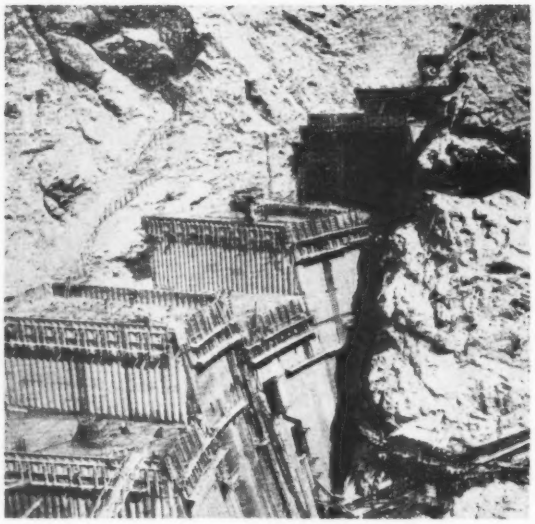

Fig. 12. View of main dam construction operations.

47,000 kw, 13.8 kv, and 0.95 power factor. They are totally enclosed and furnished with surface air coolers to provide a self-ventilating system.

Station electrical service will be 230/400 volts, four wire, 50 cycle. When the main units are operating, service power comes from either of 2-500 kva transformers fed from generator main leads. During off peak (non-operating hours) station service and operator's village supply will be from 2-1000 kw diesel driven sets located in a separate building 300 meters downstream from the reregulating dam on the left bank of the river.

The powerhouse was held as close to the dam as practical for economic reasons, but due to the double curvature of the dam, and the fact that tailwater required a relatively high draft tube deck, an area between the dam and the powerhouse at elevation 5300 resulted. Advantage of this area is taken by replacing the transformers and a portion of the switchgear here. The switchgear will be located partially in this area and partially on the roof of the powerhouse. The lighter weight equipment will be located on the roof.

Rooms below this platform area will be provided for control, offices, storage, switchgear, and auxiliaries.

Three 2.6 meters diameter steel-lined penstocks are provided through the dam. Individual intake structures for each of the penstocks are provided and a wheeled gate protects each opening for emergency closure and closure for inspection of the penstocks. The intake structures also contain the trashracks. The gates will be raised to the crest by individual fixed chain hoists. A gantry crane is provided on the crest of the dam for removal of the gates for inspection and maintenance.

The embedded portion of the penstocks is designed as a watertight membrane. Provision for drainage is provided to relieve external pressures, and resulting stresses when the penstocks are unwatered. The penstocks are of welded construction throughout their length. Inspection of welds will be by radiographic and ultrasonic methods. All longitudinal welds are to be inspected by radiograph for quality. Design working stress is 16,000 psi, and a joint efficiency of 90 percent is assumed.

Service valves will be provided immediately upstream of each unit and because of operation of the turbines as peaking units these valves will be operated daily to relieve the headwater pressure on the wicket gates.

The service valves will be 2.2 meters diameter spherical valves.

An unusual feature of the powerhouse is the depth to rock in the central portion of the river, requiring concrete backfill under the draft tubes. Advantage was taken of this feature by locating the temporary diversion conduits in this mass. The conduits are steel lined and will be backfilled and grouted when this phase of the diversion is complete.

The suppliers of the major permanent equipment of the power facilities and transmission line are indicated below in Table.

Table

PRINCIPAL ITEMS OF EQUIPMENT AND NAMES OF SUPPLIERS

Generators	2 – 37,000 kva	Hitachi	Japan
Transformers	2 – 46,200 kva	Toshiba	Japan
Turbines	2 – 49,700 HP	Harland	Scotland
Spherical Valves	2 – 2.2m dia.	Neyrpic	France
Cranes			
Powerhouse	140 metric tons	Jucho	W. Germany
Intake Gantry	20 metric tons	Jucho	W. Germany
Valve Chamber	45 metric tons	Jucho	W. Germany
Gates			
Spillway	10.0m × 10.0m	Rheinstahl	
Intake, Power	2.5m × 5.0m	Fried. Krupp & Rheinstahl	
Intake, Outlet	1.3m × 2.6m	Fried. Krupp & Rheinstahl	
Draft Tube	2.8m × 2.5m	Fried. Krupp & Rheinstahl	
Outlet Valves	2 at 760 mm	Voest	Austria
Reregulating Service Gates	2 at 1.52 × 1.22m	Ishikawa Jima	Japan
Penstocks		Voest	Austria
Elevator	1 at 1800 kg	Schindler	Switzerland
Transmission Line:			
Towers and Conductors		SAE	Italy
Hardware		Marubeni-Iisha	Japan
Diesel Generator Sets		General Motors Overseas Corporation	

Reregulating Dam

The reregulating dam is located 4000 feet downstream from the power plant (Fig. 6). It is an arch

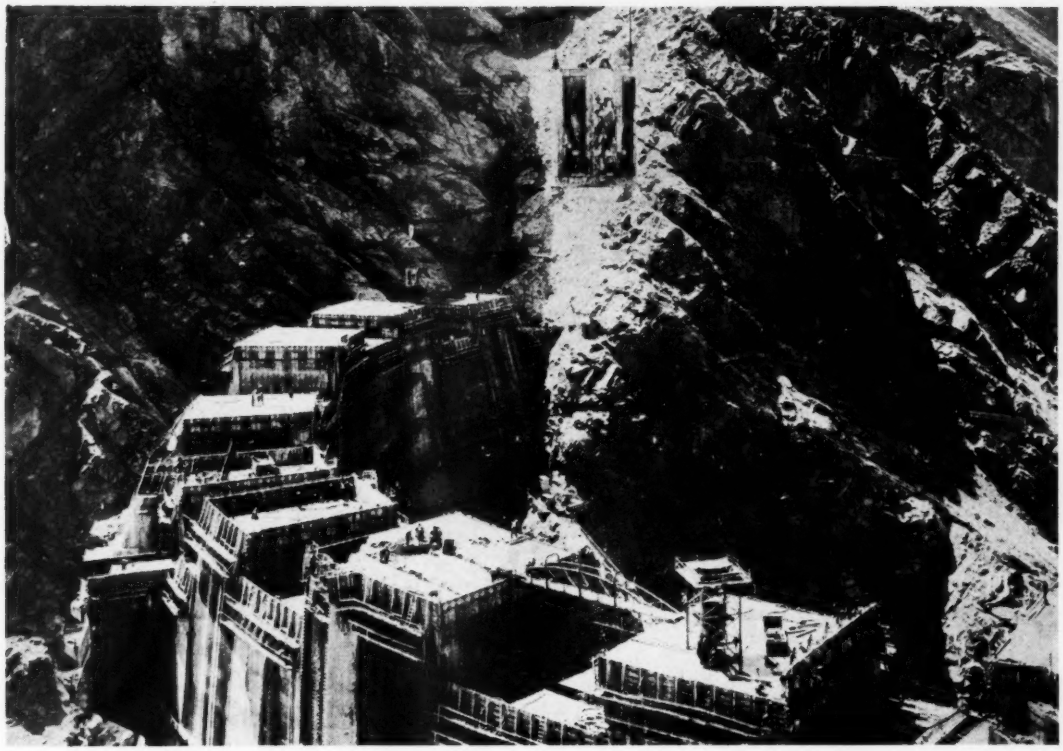

Fig. 13. Karadj Project, view looking towards left abutment.

gravity concrete dam with a centrally located gated spillway. The two spillway gates are the same size as those used in the main dam spillway. Layout of the gates and hoist and operation of the hoists will be similar to the gates on the spillway of the main dam.

The outlet works are located in the dam to one side of crest structure and consist of two 4.0×5.0 foot sluice gates. Either sluice gate will pass the maximum required discharge for downstream water demand. The two sluice gates will discharge into tailwater. Individual intake portals will give greater flexibility of operation and permit maintenance and repairs on one sluice gate while the other is in use. Air vents downstream from the sluice gates are provided. Diversion during construction will be provided by a temporary concrete lined tunnel through the right abutment. This tunnel will be plugged and abandoned after construction.

Transmission Line

The power developed at Karadj will be transmitted over a single tower double circuit transmission line to a receiving substation located in the suburbs of Tehran. The transmission line will be 33 miles long and traverses extremely rugged terrain for the major portion of the distance. Transmission is at 132 kv at 50 cycles. The alignment roughly parallels the Karadj river valley to the plains downstream and then follows the foothills until a point near Tehran. This alignment was found to be the most economical and avoided traversing the costly property of the plains between the Karadj village and Tehran. At present only one circuit will be installed on the towers, the second circuit will be installed at the time the third unit is erected in the powerhouse.

Construction

At present the Karadj project is under construction and scheduled for completion in mid 1961. The rugged topography at the damsite presented problems in the setting of the construction plant. Since very few level areas existed, most of the construction plant facilities required extensive excavation. Both fine and coarse aggregate must be manufactured and for this reason the limited storage area available is a critical point in the construction program.

Concrete placing schedule in the main dam calls for 10,500 cubic meters per week average. The concrete is handled from the batch plant in eight cubic yard buckets on rail cars to the cableway. There are two travelling head towers on the right abutment and they provide service to a major portion of the dam

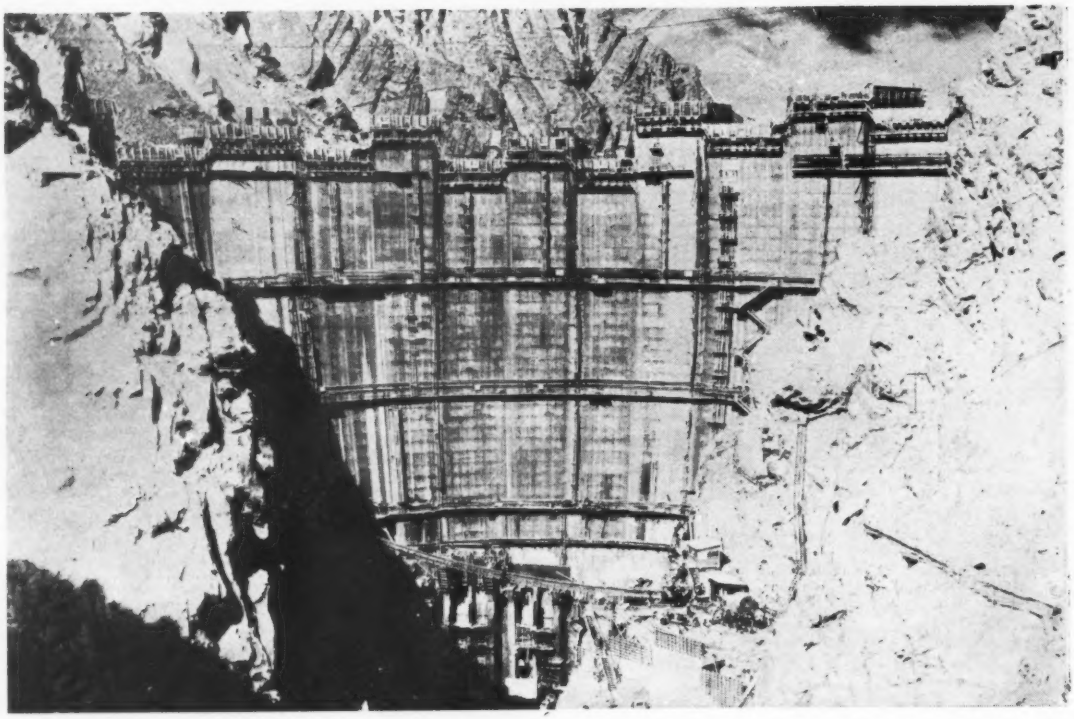

Fig. 14. View of downstream face of Dam.

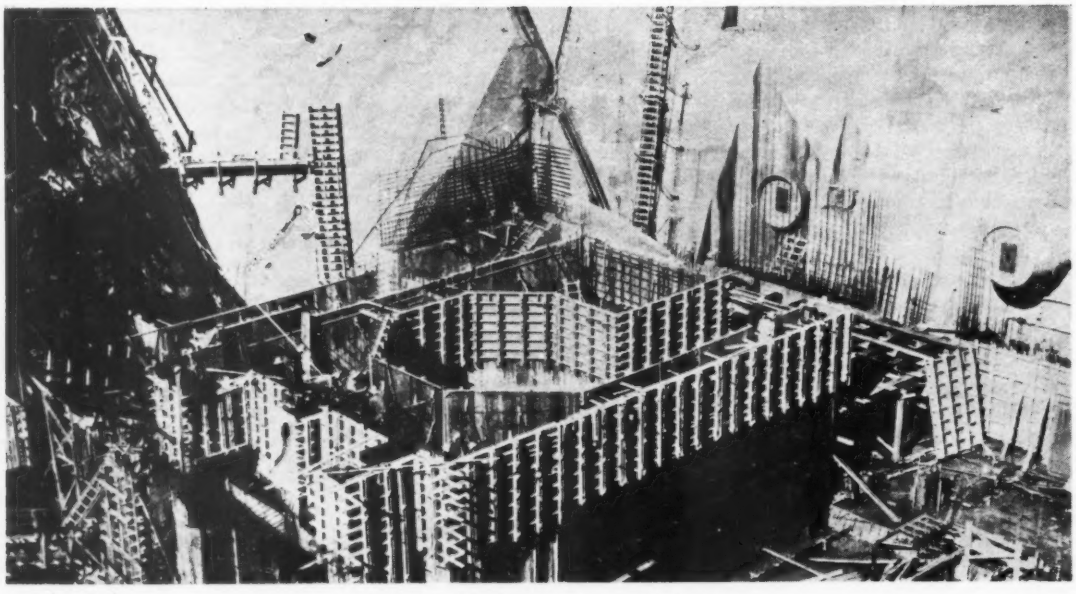

Fig. 15. Karadj Dam Powerhouse Construction.

and powerhouse. Maximum permissible main dam concrete lift is two meters. A portion of the concrete in the dam on the upper left abutment will be placed by a stiffley derrick. Also the spillway chute and bucket concrete will necessitate pumpcrete operations for placement.

During construction the Karadj river is to be diverted first through 4.9 meter diameter concrete lined tunnel in the right abutment. After the arch dam concrete has progressed sufficiently high above the canyon floor diversion will be transferred through three conduits embedded in the base of the dam and extending through the powerhouse substructure backfill concrete. Two conduits will be provided with spherical valves later to be removed and installed in the penstock system. The third conduit will be provided with a 1.5 meters diameters butterfly valve and will permit regulation of flows downstream. The magnitude of downstream releases is established by (1) the downstream demand for water supply and irrigation and (2) regulation of the reservoir elevations during construction. The spherical valves can only discharge in the full open position and provide the necessary releases for flood control.

The heaviest pieces to be shipped are the three-phase main power transformers at 47 metric tons each. Shipping dimensions are 3.54 m × 2.8 m × 4.2 m.

The steep slopes in the Karadj canyon made excavation difficult and dangerous. The many systems of jointing in the foundation rock resulted in isolated blocks that had to be removed or anchored to the abutment to prevent loosening and falling on the workers below. Even under these adverse conditions construction is proceeding rapidly and will soon be in agreement with the original schedule of 1956 calling for completion in mid 1961.

The responsible representatives of the Iranian Government for the project include S. Asfia, Deputy Director, Plan Organization and Khalil K. Taleghani, M.ASCE, formerly Director, Karadj Dam Authority. H. E. Buckert is Resident Manager for Morrison-Knudsen International Construction, Inc.; and for Harza Engineering Company, Bruce M. Johnson, M.ASCE, is Project Manager in Chicago while Robert E. Brown, AM. ASCE, is Resident Engineer.

SIGNIFICANT PROJECT DATA

Hydrology	
Drainage area—square kilometers	764
Average annual runoff—MCM	472
Maximum annual run-off—MCM	918
Minimum annual runoff-MCM	272
Flood of record—cubic meters per second	350
Maximum probable flood (spillway design flood)	1450
Reservoir	
Main dam, live storage capacity—MCM	172
Reregulating dam, live storage capacity—MCM	0.6
Additional annual water supply available because of storage—MCM	115.6
Main Dam	
Maximum height—meters	180
Length—meters	390
Volume of concrete—cubic meters	720,000
Reregulating Dam	
Maximum height—meters	50
Length—meters	93
Volume of concrete—cubic meters	35,000
Hydroelectric Plant	
Capacity, initial—kilowatt	80,000
Capacity ultimate—kilowatt	120,000
Average annual energy delivered—kilowatt-hours	149,000,000
Estimated Cost of Project	
Total US dollar equivalent	50,000,000

Conclusions

A large, multiple-purpose dam project is being constructed to provide municipal water supply and electric peaking power capacity for the City of Tehran, Iran. Water supply and power are the sources of project revenue, with flood control and irrigation as additional benefits.

The dam structure is of the double curvature arch type. During design, special efforts were exercised to test and analyse the foundation, and extensive electronic computor analyses and model tests of the arch structure were conducted.

Dam and power plant construction are complicated by problems of steep site topography, concrete cooling and joint grouting requirements, foundation grouting and under drainage problems, and extensive main highway relocation works.

The project involves problems of co-ordination involving use of local cement and aggregate by local labour in a complicated major arch dam structure constructed by an American general contractor. Additional co-ordination is required by employment of permanent project equipment from several European countries and Japan.

Design co-ordination, and construction are proceeding on schedule and the Karadj Dam Project will go into service during 1961.

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AEI 375 MW Supercritical Generating Set for CEGB

NEW STEP IN POWER GENERATION

AEI is to receive an order from the Central Electricity Generating Board for one of two 3,000-rpm single-axis 375 MW turbine-generators to be installed in the mid-1960's at Drakelow 'C' power station near Burton-on-Trent.

The sets will be the first major power units in Britain to run at supercritical pressure. Steam conditions will be 3500 psig/1100°F at the stop valve with reheat 1050°F.

The CEGB estimates that the introduction of these two new 375 MW units will result in a power station thermal efficiency in the region of 40 per cent.

In 1959, the average figures recorded by the CEGB in their three most efficient stations were 33,88 per cent, 32,63 per cent, and 32,52 per cent. These three stations are equipped with AEI turbine-generators.

The rating of 375 MW is the highest for any single-shaft turbine-generator in the country. AEI is also building the largest two-speed double-shaft unit in the country—a 550 MW set for Thorpe Marsh power station.

Continuous Progress

The company's record in the field of generating equipment is one of continuous progress and achievement. AEI built the first British hydrogen-cooled generators, installed at Littlebrook power station in 1948-49 and more recently installed at Bold, St. Helens the first large generator to have direct water-cooling of the stator windings — an important step in keeping down the physical size of generators in view of transport problems.

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D. V. Joglekar
Adviser
Fundamental and Basic Research
Central Board of Irrigation and Power, India

Research on Basic and Fundamental Problems relating to River Valley Projects and Flood Control Works

RESEARCH IN THE FIELD OF IRRIGATION AND Hydraulic Engineering is being conducted in our Research Stations for almost 30 years. But it had mostly been confined to specific problems. Research of the basic type, which in fact, forms the core of any organised research programme, had so far received only scanty attention. As such our research stations had functioned primarily as test houses, where experiments had been conducted to check up departmental proposals and to investigate problems of local interest.

As the central co-ordinating authority for all research concerning Water Resources Utilization in the country, the Central Board of Irrigation and Power got concerned about such defective state of research development, and initiated action in 1953 to formulate a scheme of Fundamental and Basic Research. This seemed of imminent importance in view of a number of multipurpose river valley projects envisaged in our Five Year Plans.

After due scrutiny by an expert Committee the Government of India approved the first scheme of Fundamental and Basic Research. It included 12 problems, and forms part of the Second Five Year Plan, with a plan provision of Rs. 105 lakhs. The problems are:

(i) Air entrainment,
(ii) Turbulence,
(iii) Cavitation,
(iv) Design of channels,
(v) Engineering properties of soils,
(vi) Sedimentation studies in streams and reservoirs,
(vii) Sub-soil flow,
(viii) Standardization of the use of surkhi and other puzzolanic materials in mortar and concrete,
(ix) Principles of mortar and concrete mix design,
(x) Studies on vibration in soil under machine foundations,
(xi) Development of economic alternatives to stone for river protection works, and
(xii) Instrumentation.

Under the supervisory control of the Central Board of Irrigation and Power, the work was assigned to different Research Stations in the country and is in progress for the last two years.

A brief description and general outline of the various problems mentioned above are given below:

I: Air-Entrainment

This problem comprises of the following specific studies:

(a) To study in detail the initiation and development of entrainment of air in high velocity flow.
(b) To study air-entrainment and economic sizes of stilling pools below high head structures.
(c) To study air-entrainment in draft tubes of various types and in vertical penstocks of underground power houses.
(d) To formulate laws governing the high speed intermixing of air and water so as to lay down design criteria for training walls, chutes, draft tubes, stilling pools and spillways.

With the trend towards high head in present-day hydraulic structures, high velocity flow has acquired an unusual interest and importance. Water flowing down with great velocity in chutes and over spillways constitutes a potential danger unless it is deprived of its excess energy. Energy dissipation has therefore become one of the integral aspects of design of high head structures.

At a certain stage, rapidly flowing water entrains air on account of the interaction of flow and atmosphere. The penomenon is characterised sometimes by 'white water' when air bubbles penetrating into the flow convert it into a milky mass. Air-entrainment reduces the velocity of flow and increases the volume of water. Knowledge of the laws governing the air-

entrainment in rapidly flowing water is indispensable to design engineers in computing spillway basins or side walls of steep chutes.

II: Turbulence

This problem comprises of the following specific studies:

(a) Studies to bring out the importance of turbulent boundary layer in hydraulic structures—open flow as well as flow in closed conduits.
(b) Study of large-scale turbulence in channels.
(c) Study of turbulence in reaction and impulse turbines and draft tubes.

It was in 1883 that Osborne Reynolds demonstrated that there are two distinctly different types of fluid flow. He injected a fine, thread like stream of coloured liquid at the entrance to a large glass tube through which water was flowing from a tank. A valve at the discharge end permitted him to vary the flow. When the velocity in the tube was small, this coloured liquid was visible as a straight line throughout the length of the tube, thus showing that the particles of water moved in parallel straight lines. As the velocity of the water was gradually increased by opening the valve further, there was a point at which the flow changed. The line would first become wavy, and then at a short distance from the entrance it would break into numerous vortices beyond which the colour would be uniformly diffused so that no turbulence could be distinguished. Later observations have shown that in this latter type of flow the velocities are continuously subject to irregular fluctuations.

The first type is known as laminar, streamlined or viscous flow. The significance of these terms is that the fluid appears to move by the sliding of lamination of infinitesimal thickness relative to adjacent layers; the particles moved in definite and observable paths or streamlines and also the flow is characteristic of a viscous fluid or is one in which viscosity plays a significant part.

The second type is known as turbulent flow, where irregular motion of a large number of particles takes place during a very brief time interval. The distinguishing characteristic of turbulence is its irregularity, there being no definite frequency, as in wave action, and no observable pattern as in the case of eddies.

Large eddies and swirls and irregular movements of large bodies of fluid, which can be traced to obvious sources of disturbance do not constitute turbulence but may be described as 'disturbed flow'. By contrast, turbulence may be found in what appears to be a very smoothly flowing stream and one in which there is no apparent source of disturbance. The fluctuations of velocity are comparatively small and can often be detected only by special instruments. Fluctuations of velocity are accompanied by fluctuations in pressure which is the reason why manometers or pressure gauges attached to a pipe in which fluid is flowing usually show pulsations. In this type of flow an individual particle will follow a very irregular and erratic path and no two particles may have identical or even similar motions. Thus a rigid mathematical treatment of turbulent flow is impossible and instead, experimental and statistical means of evaluation must be employed. Considerable success has been achieved in evaluating pipe friction for various stages of flow; but the same cannot be said of channels which present great difficulties on account of their free water surface.

Thus turbulent flow is a very important phenomenon in hydraulic engineering. It is due to this state of flow in rivers and channels that the bed and suspended loads are carried down from the hills to the sea. In the case of submersible bridges, uplift pressures are due to instability of flow or turbulence. In the case of fully submerged or partially submerged bodies, form-drag is a very important factor.

The extent by which a hydraulic structure is contracted, as for instance in an aqueduct, determines the state of flow in the structure, viz., whether it would be subcritical or hypercritical, which in turn affects the dimensions of such structures. The angle at which the flow approaches a river or a canal bank causing diving, curved flow is also one of the factors causing turbulence which may lead to erosion of banks, the extent of erosion depending upon the intensity of turbulence and the bank material.

Highly turbulent flow exists when standing wave forms, as for instance near the toe of a spillway, where velocities and impact pressures are changing so rapidly that the partition walls or the guide banks are sometimes subjected to fatigue and perhaps to failure unless they are properly reinforced.

This type of turbulence can be detected only with the help of pressure cells and oscillographs. Hot wire or Film anemometers and Oscillographs are also used to determine turbulent velocity fluctuations.

The decay of turbulence or the distance in which the residual turbulence after leaving the stilling basins disappears is an important problem for designing protection works downstream of falls and spillways. Energy of turbulence can never be recovered and is ultimately lost through dissipation into heat.

III: Cavitation

It is intended to cover the following specific studies under this problem:

(a) *Civil structures*—relation between magnitude of negative pressure and cavitation damage and investigations on the resistance of protective coatings against cavitation damage.

(b) *Hydraulic machinery*—protective coatings against cavitation damage.

The possibility of cavitation in hydraulic machines was recognised as long ago as 1754 by Euler in con-

nection with the theory of turbines. Reynolds in 1894 was the first to initiate experimental work on this subject. From there onwards, the subject is receiving widespread attention. In 1924, pump and turbine manufacturers understood the effect of cavitation on the runners of turbines, similarly erosion on propellers of ships was also noticed and extensive research is being pursued by the laboratories in Europe and United States. In India interest on this subject was roused by the extensive damage which occurred is the world's largest Volute Syphons at Hirebhasagar in Mysore State. Since then many hydraulic research stations in India are actively engaged in these investigations.

In modern technological times speed is continuously 'accelerating' to its upper bound. This is true of hydrodynamic systems as well where higher speeds and lower pressures have brought to the fore the problem of cavitation. For sometime past cavitation was known more by its effects than by the physical processes involved. Damage to materials by erosion, losses in efficiency of hydraulic machines, objectionable vibrations and attendant noise and increase of resistance of submerged bodies on onset of cavitation have been known to follow in the 'wake' of cavitation.

Bernoulli's equation for steady incompressible flow states that the total energy of flow is constant; however it does not imply any restriction on the absolute magnitude of pressure in zones of high velocity. In an incompressible liquid, this relation holds until its vapour pressure is reached when bubbles of vapour and dissolved gases form about the minute particles or nuclei of foreign matter in suspension. Cavitation signifies the vaporisation in flowing liquids as the result of velocity changes which reduce the pressure to its vapour limit. When cavitation is incipient, tiny vapour bubbles form in rapid succession at the point of lowest pressure and are carried downstream by the flow when the bubbles or cavities reach a zone of higher pressure, they immediately collapse or implode as the vapour within them condenses. This process of formation and collapse is instantaneous, so far as the naked eye is concerned, which characterises the opaque blur that can be distinguished. When countless vapour-filled cavities implode, water rushes in radially to fill the space. The sudden arresting of motion as the vapour finally vanishes results in extremely high pressure intensities over small pinpoint zones. This local high pressure is transmitted radially outward with the speed of sound followed by a negative pressure wave which may lead to one or more repetitions of the vapourization-condensation cycle. Solid boundaries subjected to repeated reversal of high stresses due to the bombardment of collapsing cavities at or near the boundary surface finally become pitted or corroded and may eventually fail through fatigue.

In high head hydraulic structures, danger of cavitation always exists unless it is prevented by adopting the so-called cavitation-free design. Cavitation on profiles of spillways, chute and friction blocks, end sills in stilling basins, syphons, high pressure conduit outlets is of interest to the design engineer. In hydraulic machines such as pumps, turbines and propellers cavitation not only impairs efficiency but brings about physical damage.

IV: **Design of Channels**

(a) To study sediment characteristic and other factors affecting the regime of channels and to standardize the design of alluvial channels under controlled discharges and grades and charge of sediment carried by the channels.

(b) To verify and ascertain the applicability of the numerous formulae for measurement and estimation of bed load transportation of various sands.

(c) Determination of rugosity coefficient of lined and unlined channels.

(d) Collection and analysis of hydraulic data for stable channels (both alluvial and non-alluvial).

(e) To study the effect of silt charge on the coefficient of various discharge measuring devices.

The subject is very comprehensive and involves innumerable factors and has been under study in India for a very long time. This subject is very important as proper solution of it could lead to correct design of channels with least maintenance cost. Earlier workers like Kennedy and Lindley of the Punjab correlated the depth of channel with a non-scouring and non-silting velocity. But this relationship held good only for certain stable channels in the Punjab carrying a particular grade of bed material. It was only in 1930 that Mr. G. Lacey evolved a set of formulae which took into account the grade of bed material. He also showed that, wetted perimeter depends on discharge alone. In practice, however, it was found that there was considerable divergence in actual channel dimensions from the dimensions arrived at by the Lacey formulae, even though the former were fairly stable. This has been ascribed to the load of material carried along the bed and in suspension not being considered as a separate factor by Lacey.

Another line of approach to this problem, viz., Tractive Force Theory was followed by various research workers in United States like E. W. Lane, H. A. Einstein and others; work on similar lines has also been done at the Central Water and Power Research Station, Poona.

In the proposed investigations, observations will be carried out in the field for channels which are considered to be stable. The observations will include discharge and velocity measurements and measure-

ments of the bed and suspended load with suitable samplers. In addition to the field observations, studies will be done in flumes in the laboratories to determine the behaviour of various materials carried by channels along the bed and in suspension.

It was commonly believed that the rugosity coefficient was primarily a function of the boundary material. It has now been realised that it is influenced by several factors such as size and channel conditions. The sediment load is also possibly another factor which influences the flow in so far as it affects the rugosity coefficient as has been claimed by Vanoni. Roughness again appears to be a function of the ratios of particle size and Reynold's number and channel parameters like depth : width ratio, etc. All these factors require closer investigation.

As regards the effect of silt charge on the coefficient of discharge of various measuring devices, it has been found by research workers in America that addition of silt increases the velocity in the channel, for instance 0.15% of addition of silt charge in suspension caused almost a uniform increase in velocity by about 10 per cent. It is still not known whether this increase is maintained or has some limit.

V: Engineering Properties of Soils

(a) Determination and interpretation of engineering constants of soils like soil modulus, permeability, consolidation coefficient, etc., on the basis of in situ tests.

(b) Soil compaction studies—effect of density, pore pressures and permeability due to different modes of compaction, variation of moisture content, etc.

(c) To investigate swelling pressures in clay soils.

(d) To investigate the effect of remoulding of different types of soils on shear characteristics.

(e) To correlate mechanical and mineral composition and clay structures of different soils of India with their engineering properties.

(f) Soil stabilisation—
  (i) with admixtures,
  (ii) by electro-chemical treatment,
  (iii) by injection.

This problem covers a vast field of research on the behaviour of soils in engineering structures, the importance of which cannot be overstressed. Soils differ from region to region but they can be broadly classified into alluvial and non-alluvial. Non-alluvial soils vary greatly from each other such as lateritic soil, red soil, black cotton soil, yellow soil, etc. Various laboratories in the country are engaged in this work on specific projects. They will now study this problem on basic principles to find the correlation of various constants and characteristics of soil in situ in the field and remoulded soil samples in the laboratory. Soil stabilisation in (f) above has a very important bearing on practical application, viz., stabilizing the foundations of earth dams either by electro-chemical treatment or by injection. Stabilizing the foundation by clay injections has been a common practice in the United States; this method was also adopted recently in the Kotah Barrage on the Chambal River in Rajasthan.

VI: Sedimentation Studies in Streams and Reservoirs

(a) Collection of data relating to bed and suspended load of streams and reservoirs so that life of reservoirs can be correctly estimated.

(b) Determination of nature and behaviour of density currents and their influence on sediment deposits in reservoirs.

(c) Model studies of density currents including flume studies and their applicability to prototype.

(d) Meandering, braiding and avulsions of river and their prevention.

The useful life of a reservoir is reduced by sedimentation if the decreased storage capacity affects the supply of full services for which the reservoir is designed. Even when sedimentation occurs in reservoirs the damage potential is different depending upon its service functions. For example, in a storage reservoir used for regulating discharge for power production, the decrease in storage capacity will necessarily affect it. On the other hand a run-of-river plant in which the reservoir merely develops a head, is not affected by silting. However, in both these cases if the coarse sediment gets diverted to the off-take, it presents a potential source of damage to the turbines. In flood control reservoirs the size of flood, which the reservoir is meant to control fully, will be adversely affected by sedimentation which will also increase the frequency and magnitude of flood damage downstream. In irrigation and water-supply reservoirs which are normally designed for high ratio of capacity to inflow, sedimentation disrupts continuity of supply in periods of famine as also in satisfying anticipated rise in demand for water. In natural streams sedimentation is intimately linked up with the phenomena of meandering. In aggrading, degrading and stable rivers sedimentation plays a vitally important role; in fact, the rivers assume the characteristics solely on account of the nature of sedimentation.

There is an urgent need for conducting the study of sedimentation in natural streams and reservoirs as also in hydraulic scale models.

Various Research Stations have been asked to collect the data of the load carried by the streams. This data will be very useful in determining the life of reservoirs.

This subject has been engaging the attention of the Central Board of Irrigation and Power for the last so many years and some information regarding rate of silting in the reservoirs is available. But much more

work still remains to be done. The following eight reservoirs have been selected for carrying out capacity survey and observation of density currents.

(1) Bhakra (Punjab).
(2) Hirakud (Orissa).
(3) Panchet Hill (D.V.C.).
(4) Maithon (D.V.C.).
(5) Gandhi Sagar (Madhya Pradesh)
(6) Matatila (U.P.).
(7) Tungabhadra (Mysore).
(8) Lower Bhawani (Madras).

VII: Sub-Soil Flow

This problem comprises of the following specific studies:

(a) Tube-wells.
(b) Structures on permeable foundations
(c) Canal linings
(d) Earth and rock fill dams
(e) Water-logging and drainage

Irrigation by tube-wells is being practiced on a large scale for the last so many years in U.P. and recently in Bihar. In the Punjab, tube-wells are used for lowering sub-soil water-table by pumping. Very interesting studies have been undertaken in U.P. regarding the effect of intensive tube-well irrigation on sub-soil water-table. Basic studies are now proposed to be done to standardise the design of tube-wells under varying conditions of soil profiles and sub-soil water conditions.

As regards structures on permeable foundations, this is a science of sub-soil hydraulics in relation to the design of structures and can be said to have begun with propounding of Darey's law governing the flow of water through permeable soils. Experiments for checking this law have been carried out by a number of investigators in India and abroad. Bligh's theory of creep was simple but without sufficient experimental background. In 1920 Pavlovsky approached this problem from the analogy of flow of electricity through a conductor. Laboratory results, however did not agree with field results. In 1926-27 trouble arose in the syphons in the Upper Chenab canal (Punjab). Repairs carried out on the Bligh's accepted theory did not give good results and the trouble persisted. Pressure pipes inserted indicated that actual pressures had absolutely no relation with those calculated from the Bligh's theory. After a number of observations carried out by Dr. A. N. Khosla in 1930, simple creep theory was shown to be wrong.

Investigations on uplift pressures in dams were also carried out in U.S.A. by a number of workers, like Lane, Julian Hind and others. Notable contribution was from Dr. Terzaghi regarding floatation gradients and the hydraulic gradient at exit and its effect on stability of structures. Since then various experiments have been done in India and abroad and Dr. Khosla propounded a theory for the design of weirs and other structures on permeable foundations and his theory and details are published in the CBIP Publication No. 12. It was, however found that this theory was applicable in cases where the sub-soil is completely pervious and of infinite depth and only in cases where the hydraulic structure is very wide; considerable divergences were, however, found in the case of canal head regulators—a three dimensional problem—and where sub-soil consisted of layers of differnt permeabilities.

VIII: Standardization of the use of surkhi and other puzzolanic materials in mortar and concrete

The following specific studies are proposed to be covered under this problem:

(a) Determination of suitable indices for puzzolanic activity.
(b) Standardization of puzzolanic materials and the conditions under which they can be suitably used.

Surkhi is being used both with lime and cement fairly extensively, thus effecting large savings. The type of clay to be selected is very important. Raw materials for puzzolan are so diverse that the chemistry of puzzolana has to be investigated to make the best selection of the material. Savings in cement can be effected to the extent of 15 to 30 per cent. In the construction of Bhakra Dam alone, about 150,000 tons of cement are expected to be saved by the use of local surkhi.

In the past many attempts have been made on studying surkhi; but the tests conducted and results obtained so far were of considerable significance from a study of individual samples of surkhi only. No general standardization of surkhi has yet been possible as there are conflicting opinions regarding the suitability of different types of surkhi such as under-burnt, over-burnt and well-burnt. Few attempts at determining the mineralogical composition of surkhi have been made, but no systematic data are available on the mineralogy of surkhi clays and other puzzolanic activity. The object of taking up this problem therefore is to determine suitable criteria for puzzolanic activity and to standardize such materials and the conditions under which they can be used with the same confidence as cement.

IX: Principles of Mortar and Concrete mix design

(a) To investigate and arrive at suitable methods of designing mortar and concrete mixes.
(b) Basic research in concrete and mortar mix design in relation to permeability, thermal properties and dynamic modulus of elasticity.
(c) To investigate the suitability of materials for mortar and concrete; (i) aggregate, (ii) cement and hydraulic limes, (iii) air-entraining agents.

(d) To study alkali reactivity and petrographic characteristic of aggregate.
(e) Investigations relating to strength of masonry and concrete.

The present practice of concrete mix design involves a principle that a particular combination of coarse and fine aggregate fractions, depending on the individual grading and particle sizes, shape etc., gives the best and most economical concrete. Grading curves based on whether aggregates are natural and/or manufactured are prescribed to achieve the best results. In practice, however, we may have to take into account several local factors in evolving a rational concrete mix design for any particular job. For instance some of the aggregate fractions may be composed of naturally occurring while the remaining, manufactured; in such cases the ideal combination shall have to be worked out to achieve optimum results from the resulting concrete.

X: Studies on vibrations in soil under machine foundations

(a) Fundamental studies of stresses in soils under foundations due to machine vibrations. ,
(b) To evolve a rational design for foundations under machines.

The object of this problem is to collect sufficient data to enable us to design foundations for heavy machines on a rational basis. The design of foundations on which heavy machinery like steel plants, hydraulic power machines—especially when placed in deep soils—requires great care. Due to the vibrations set up by these machines, the soil underneath and surrounding the foundation is subject to high stresses and due to fatigue caused thereby, the foundation may give way causing heavy loss. Similarly it has to be seen how far apart machines should be placed so that vibrations set up by these do not synchronise. In the absence of any method for determining the dynamic engineering properties of soil for undisturbed samples —ideally representative of soil en-masse in situ, it is felt that the mechanical vibrator should be ideal though this is of a recent application. Investigations carried out elsewhere have shown promise of utilizing this method in routine analysis of the engineering properties of soils.

XI. Development of Economic Alternatives to Stone for River Protection Works

Stones are commonly used for river protection works. They are not easily available in alluvial plains or deltaic regions and if they are used for any bank protection works, they have necessarily to be brought from great distances. This naturally increases the cost of the work. Such costs are not only disproportionate but also often deterrent to the undertaking of a big bank protection work in such areas. The object of this investigation is therefore to see whether locally available soils can be stabilised and strengthened with the addition of lime, cement etc.

XII. Instrumentation

In recent years there has been a great advance in instrumentation for carrying out model experiments in Europe and America and the Research Stations in India are also not lagging behind, though the progress is slow due to non-availability of certain electronic component parts of the equipment. The condition will improve as soon as the position of foreign exchange is eased. Several instruments have already been produced by some of the well established Research Institutes in the country and as the work progresses we will be manufacturing our own instruments for all practical purposes.

Foreign exchange has now been released by the Government of India for the purchase of immediate requirement of equipments from abroad. It is expected that more rapid progress will be made in furthering the studies on all the twelve problems which will have to be continued in the Third Plan Period as well. In addition to the above, seven more new problems are proposed to be undertaken for study in the Third Plan. The new problems with their general outline are given below:

XIII: Utilization of Isotopes in Sub-Soil Investigations and Soil Compaction Control

Radioactive tracers are becoming an important tool for hydrological and soil studies because of the low cost, ease of detection, small gravimetric quantities required and absence of density problems. Of course in carrying out these experiments suitable precautions have to be taken against radiation hazards.

The perfect research tool for obtaining mass data on soil moisture and density should be fast and accurate in operation, should be able to measure moisture in any state (water, ice, or vapour), and should leave the soil structure undisturbed so that repeated measurements can be made at the same point over a long period of time. No existing equipment or method of operation can fulfil all the requirements. There is also a demand for a simple device for quick measurement of moisture and density in the surface layers of soil during embankment construction. Such equipment would be invaluable in compaction control. Here again present methods are laborious and time consuming and density determinations are relatively inaccurate unless great care is used. The small size of the density sample makes it necessary to average several determinations in order to get a value representative of a large volume of embankment material.

The object of this investigation is therefore to determine the soil moisture and density with radioactive tracers and suitable measuring devices. Considerable

amount of work has already been done in United States on this subject.

XIV: **Investigation on Soil Compaction of different Soils in Wet Conditions and Standing Water with particular reference to Construction of Earth Dams**

The present practice of constructing earth dams lays stress on the adequate moisture content to which a soil is brought prior to compaction. Moreover, moisture content is recommended to be maintained either slightly below or above the optimum moisture requirement of the particular earth material intended to be used for such construction; but building of an earth dam in wet conditions and in standing water is generally not favoured. Likewise, the use of hard clays is forbidden for construction of earth dams by the usual methods. In other countries (especially in the United States), where the rainy season is uncertain there is now an increasing tendency to modify the technique of construction of earth structures aiming at carrying out work even during the rainy season and using sufficiently wet soil material for compaction during construction. They are also permitting use of the heavy clayey soil in construction of earth dams.

In view of the proposed dams in high reaches where, apart from the complex nature of the material available for use in construction, the dry period which is normally considered suitable for construction of earth structure is limited due to heavy rainfall. There is, therefore, very urgent need for research on our part to reorientate the prevalent conception of moisture requirement in relation to the particular type of soil so as on one hand to minimize development of undue pore pressure and on the other, undertake such construction work during greater part of the year, including some part of the wet season which is not done at present with a view to extend the construction period in wet areas.

XV: **Development of Precast Techniques in Hydraulic Structures**

These may be:

(1) Barrages, Anicuts and overflow structures.

(2) Canals structures like falls, aqueducts, syphons etc.;

(3) Hydroelectric structures and dams etc.

There has been a great advance in U.S.S.R. in using precast slags, pipes etc., manufactured at a central place and carried to site for construction of canals and distributaries of head regulators, canal falls, aqueducts, syphons etc. According to our present practice all such works which are naturally scattered over a large area are constructed individually. With the help of precast units great deal of savings as well as greater speed in completing the works can be attained.

XVI: **Minimising Loss of Head through Improvement of the Design of Trash Racks, Penstocks, Gates, Spiral Chambers, Draft Tubes, Downstream Floor and Silt Disposal Techniques on Hydroelectric Structures**

When the available heads for creating electrical energy is small, any small saving in head by reducing losses, increases the efficiency enormously.

XVII: **Minimising Losses due to Absorption Percolation and Evaporation in Still and Flowing Waters on Irrigation Works**

Seepage losses for canals are quite heavy. Observations carried out for twenty years on the Ganga canal system in U.P. revealed the following startling facts:

(1) Supply utilized in actual irrigation of crops – 56%.

(2) Losses in main canal – 15%

(3) Losses in distributaries – 7%

(4) Losses in village water courses – 22%.

Reducing these losses by suitable lining materials is obvious, Similarly losses from surface of reservoirs due to evaporation is also heavy. In Deccan areas they have been found to be of the order of 6 to 8%. It is possible to reduce these losses with the use of cetyl alcohol and other similar chemicals. The object of this investigation is to find out such substances and how best we can utilise them on the surface of tanks and reservoirs.

XVIII: **Selection, Processing and Specification of Aggregates**

Selection, processing and specification of aggregates both fine and coarse for concrete work in hydraulic structures along with the study of thermal properties and physical characteristics of aggregates and behaviour of concrete under prolonged submergence and continuous wet conditions with particular reference to entry of water in air-pores.

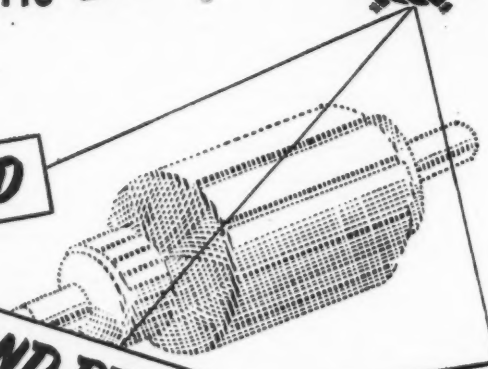
XIX: **Stress Analysis in Dams and other Allied Structures**

It is intended to determine stresses which are developed in models of dams etc., by loading them with heavy chemicals such as Mercury to simulate actual water loads in a dam. This information will be helpful in improving the designs of dams.

PARAMEX

SYNTHETIC ENAMEL COVERED WINDING WIRES

ICC



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India's First Atomic Power Station

Siting and Present Progress

INDIA WILL REQUIRE A SUBSTANTIAL INCREASE IN THE electrical generating capacity to meet her fast-developing economy and it is anticipated that against the present installed capacity of less than 6 million kilowatts, the requirements would, in about 25 years, reach a target of well over 50 million kilowatts. Even then the *per capita* installed capacity would fall short of 0.1 kilowatt. Considering the present and the immediate future, it is admitted on all accounts that electricity ranks as a major limitation on industrial output and is tending to become a bottleneck to the expansion of industries even during the Third Five Year Plan.

The total hydro electric capacity in the country including the potential situated in the difficult reaches of the Himalayas and in regions of low power demand is just about 43 million kilowatts (at 60% load factor) and not more than half of this is likely to be exploited economically during the next 25 years or so. Even now, the newer schemes for development of hydro electric power are tending to be more expensive than the earlier ones as more difficult sites have to be developed. It is now generally agreed that the balance of advantage is swinging in favour of thermal power as opposed to hydro power. Indeed this trend is borne out by a comparison of the anticipated increase in the installation of thermal capacity during the Third Plan which is about 3,000 MW as compared with less than 700 MW during the Second Five Year Plan. The comparative figures for the installation of hydro power are 2800 MW for the Third Plan and 1740 MW for the Second Plan.

As far as development of thermal power is concerned, reliance will have to be placed primarily on coal. The oil resources in the country are being explored and some trial drillings have proved to be successful; however, even as more oil is discovered in the country, it is felt that its role in the generation of power will remain limited due to the rapidly growing demands of the transport sector of the economy. Whilst thermal power generation at or near pit heads should be taken up intensively (as, indeed, has been the emphasis even for the thermal power stations to be established during the Third Plan), large-scale thermal power generation at regions remote from coalfields poses many problems.

The coal production target for the Third Plan which was initially set at 110 million tons per annum has had to be scaled down to 97 million tons and doubts are being expressed whether even this target would be achieved. In addition, from the point of view of conserving the better grades of coal for metallurgical purposes, only medium or lower grades of coal would be available for power generation. In areas close to the coalfields, this should not present serious difficulties as the lower grades of coal or middlings could be used for power generation without undue effect on the economics. The problem, however, is quite different in circumstances where long distance transport is involved. As lower grades of coal are used, large quantities of useless matter would have to be transported along with the coal, thus accentuating the already difficult problems of transportation of coal and forcing the intrinsic price of coal upwards.

Based on these considerations, the Atomic Energy Commission has come to the conclusion that in areas remote from coalfields, large atomic power stations can be built and power generated economically, even at present, as compared with thermal power based on coal which has to be transported over long distances (say 700-1,000 miles). The Government of India, on the recommendation of the Atomic Energy Commission, have decided to establish during the Third Plan an atomic power station of 300 MW (E) capacity, consisting of two reactors each of 150 MW(E)

capacity. The Atomic Energy Commission has proposed the installation of some more stations during the Third Five Year Plan; no decisions, however, have so far been taken on these proposals.

For locating the first atomic power station, the West Coast region of India was chosen in view of the rapidly rising power demands, inadequacy of alternative sources of power and the very long lead involved for the transport of coal. The existence of well developed power systems in the region has made it feasible for operating an atomic power station at a high load factor, which is necessary to ensure satisfactory economics. It was decided to locate the station on the sea coast so that sea water cooling could be employed and problems of disposal of radio-active effluents from the station minimised.

Factors governing siting

A systematic examination of the coastal region from Bombay to the Gulf of Cambay was begun in August 1959. All available information pertaining to the region was assembled and the examination revealed that four coastal sites deserved further scrutiny. They were

TABLE I

Site	*Location*	*Distance north of Bombay (miles)*
I. Borsi	South-west of Surat	140
II. Tadgaon	South of Daman	90
III. Tarapur	North-west of Palghar	62
IV. Dahej	West of Broach	210

The technical and economic considerations affecting the choice of a site were

(a) Availability of adequate quantities of cooling water;

(b) Good foundation conditions and seismic stability;

(c) Health and safety considerations under normal and abnormal operating conditions;

(d) Electrical considerations affecting the despatch of power; and

(e) Access to site, availability of fresh water, construction materials, etc.

The relative importance of the different criteria stated above would depend on the conditions that might obtain in any particular region where the station is to be situated. One may quote here from a paper by Farmer and Fletcher, "The final selection of sites will be related to features peculiar to individual countries such as the number of available places which satisfy the general engineering requirements, local climatic conditions and population distribution. These features vary from country to country, as also will the emphasis placed on them."

Before a systematic examination of the different locations could be made, it was necessary to assemble all available information and also organise new surveys. For example, to study the suitability of the sites from the point of view of cooling, hydrographic surveys to obtain the off shore contours and tidal current data had to be organised. Similarly, for ascertaining the foundation conditions, trial drillings had to be taken at the alternative sites. For evaluating the health and safety aspects of siting, a number of environmental data had to be collected. A detailed study of the electrical systems in the region into which power from the atomic power station would be fed had to be carried out. We shall now briefly examine the merits of the different sites from the point of view of the various criteria listed earlier.

Cooling requirements

A major engineering consideration affecting the location of the station was the availability of adequate quantities of cooling water. For direct cooling of a 300 MW atomic power station, about 1,000 cusecs (22.5 million gallons per hour) of water are required. The two perennial rivers of Tapi and Narbada flowing in the region carry heavy flood discharges but their dry weather flow is quite small being 280 cusecs in the case of Tapi and 500 cusecs in the case of Narbada. It was, therefore, necessary to consider a sea coast location if direct cooling had to be used.

The Naval Hydrographic Office of the Indian Navy carried out the hydrographic surveys at sites I, II and III between 17th November, 1959 and 24th December, 1959. At site IV (Dahej), the Marine Survey Division of the Bombay Public Works Department had conducted a hydrographic survey in connection with the development of a minor port in the area. Table II summarises the position of the different coastal locations from the point of view of suitability for sea water cooling.

TABLE II

Site	*Lead length for 3 fathoms*	*Lead length for 4 fathoms*	*Remarks*
I. Borsi	12,540 ft.	17,650 ft.	Very unsatisfactory
II. Tadgaon	12,500 ft.	13,550 ft.	Very unsatisfactory
III. Tarapur	4,500 ft.	5,000 ft.	Satisfactory
IV. Dahej	Very long	Very long	Very unsatisfactory
	Even the distance between high water and low water is in excess of 2 miles.		

Note : A minimum depth of 3 to 4 fathoms would be required for the sea water intake of the station.

As may be seen from Table II, sites I, II and IV were very unsatisfactory as the cooling system, apart from being very expensive due to the very long lead

Aerial photograph of Tarapur
Atomic Power Station Site.

involved, would give rise to serious constructional problems. Furthermore, in all the cases I, II and IV, as was revealed from the hydrographic survey, the coastal regime was unstable and was subjected to considerable changes. Only at site III, viz. Tarapur, the lead length was less than a mile and the coastal regime was also stable, thus making sea water cooling feasible.

Foundation conditions

For the foundation of reactor structures, the average load intensity is very high; this is about 3 tons per sq. ft. and may reach a value as high as 10 tons per sq. ft. Thus the bearing capacity of the ground for founding reactor structures should be very high. An important consideration concerning the foundation for reactor structures is the requirement that no differential settlement whatsoever between the different parts of the reactor and its primary coolant circuit (including heat exchangers) can be permitted. Another consideration of considerable importance is the likelihood of earthquake disturbances; this is important even for conventional structures. But in view of the extremely high standard of structural integrity required for an atomic power station, the question assumes much greater significance. Thus good foundation conditions and absence of a history of earthquake disturbances at the site chosen would mean considerable economies as otherwise expensive foundations and structures would be necessitated.

An examination of the geological map of the West Coast of India showed that Tadgaon and Tarapur lie in the Deccan part where the sub-stratum is solid lava formation known as Deccan Trap. This geological formation would generally be suitable for founding any type of structure. The coastal regions near Borsi and Dahej, however, have a recent formation of alluvial deposits. As far as the seismic stability of the region is concerned, the Deccan part of India is immune from earthquakes. Of the 76 disastrous earthquakes that have visited India during the last two centuries, the part of India south of the Satpuras has been immune from any violent disturbance.

To assess the foundation conditions, a number of bore-holes were sunk at the different sites. The trial borings taken at Borsi showed that even upto a depth of 50 ft. from the surface, no rock was struck. The deposits were of recent origin and had poor bearing capacity. The results of the penetrometer tests also confirmed the unsatisfactory nature of this site from the point of view of foundations. Seven bore-holes were taken at the Tadgaon site. The over-burden varied from about 9 ft. to about 30 ft. The top layers of the rock was generally found to be weathered. However, good basalt was met at a depth of 25 ft. in the case of some bores and about 40 ft. in the case of others. The exploratory bore-hole investigation at the site indicated that the top layers of compact and cemented sand and clay and murrum could be used for founding lightly and moderately loaded structures whilst for heavily loaded structures, it would be necessary to transfer the loading to solid rock. It was, therefore, concluded that the foundation conditions were fairly satisfactory.

At Tarapur site, seven holes were taken during the preliminary investigation. Rock was struck very close to the surface, the overburden varying from almost nothing to about 7 ft. The exposed foreshore area, in fact, consisted of extensive rock outcrops. The top layers of the rock were found to be weathered and fissured; however, sound basalt was met at 15-25 ft. from the surface. From this investigation, it was concluded that Tarapur site offered good foundation conditions for heavy structures such as reactors and turbine house; in fact, the site was the best of the alternative sites where foundation conditions were investigated during the preliminary bore-hole programme. At Dahej site no trial drillings were taken as the geological formation was similar to that at Borsi site.

Health and Safety Considerations

The normal operation of an atomic power station should not entail any serious limitation on the choice of a site. Reactors of the type now being built discharge small amounts of gaseous and liquid effluents during normal operation and precautions can be taken to ensure that these cause no health hazards to

the surrounding population. However, since atomic energy is still a young industry, a cautious attitude is adapted towards siting of reactors till sufficient operational experience is accumulated. The assessment of the site, therefore, had to take into account abnormal operations including accident conditions. For this purpose a number of environmental considerations had to be examined and these were

(i) Population distribution,

(ii) Meteorological conditions,

(iii) Agricultural and dairy activity, drinking water-supply sources, etc.

A team of health physics experts visited the alternative sites to make a detailed examination of these factors.

Table III gives the details of the population distribution around the alternative sites within a radius of 1, 2, 5 and 10 miles.

TABLE III

Site	*One mile radius*	*Two miles radius*	*Five miles radius*	*Ten miles radius*
I. Borsi	—	1700	7800	55000
II. Tadgaon	1200	6600	26000	86000
III. Tarapur	600	6000	29000	76000

Note : Site IV, Dahej, was not examined in this respect as by that time the site had been found to be unsuitable from technical and other considerations.

From the point of view of population distribution in the immediate vicinity, Borsi site showed to advantage though the nearness of Surat with a population of 3 lakhs (about 16 miles away) and of Navsari with a population of 50,000 (about 11 miles away) were adverse factors. The Tarapur and Tadgaon sites were more or less equally acceptable from the point of view of population distribution.

Generally speaking, the West Coast region exhibits a rather similar climatic pattern and the meteorological characteristics were more or less similar at the alternative sites considered. A factor of some considerable significance in the choice of a site was the likelihood of inversion conditions being established which would, in the event of an incident, prevent satisfactory diffusion of any radio-active clouds that might escape from the site of the power station. It was generally found that from the point of view of meteorological considerations, the alternative sites investigated did not have characteristics which would make such a situation probable.

During their surveys, the health physics team also collected considerable amount of local information about food habits, agricultural practice, vegetation, soil condition, live-stock distribution, marine produce, etc. Particular attention was paid to the question of any possible contamination of drinking water supply which might be serving communities in the neighbourhood. Dairy farming and such other activities which might give rise to biological concentration of any activity that might escape from the station were also examined. The feasibility of effecting controlled discharge of radio-active effluents, though the need for such effluent disposal would be extremely limited, was also examined. The health physics team found that from these points of view, the three sites investigated by them (viz. I, II and III) were more or less equally acceptable.

Electrical Considerations

When the Government of India decided to locate the atomic power station in the western region, it was with a view to meeting the rising power demands of the States of Gujerat and Maharashtra. The power system supplying the Bombay region of the Maharashtra State and the power system of Gujerat State were to be interconnected by double circuit 220 KV transmission lines. The atomic power station is to feed power into the Maharashtra and Gujerat power systems through the 220 KV lines. The location of the atomic power station was, therefore, to be such as to enable power to be supplied to both the systems with the lowest possible transmission losses.

In making a study of the influence of siting on transmission losses, it was necessary to examine the integrated power flows to the north and to the south over the entire life of the station. A detailed study of the existing power systems of the Bombay region of Maharashtra and of Gujerat was carried out to determine the probable scheme of load despatch in the two directions, keeping in mind the need to operate the atomic power station at a high load factor, the availability of water for the hydro stations of the Bombay system and other relevant operational factors. The study revealed that locations between 60 and 160 miles north of Bombay were almost equally acceptable and the differences in transmission losses, when considering the integrated power flows over the life of the station, were only marginal. Locations further north (for example, Site IV, Dahej) were at a disadvantage from this point of view.

Other factors

In addition to the primary considerations discussed above, other factors such as access to site, availability of fresh water, constructional materials, etc. were also looked into. The construction of a large atomic power station involves transportation of heavy and awkward sizes of plant and equipment. For instance, single pieces weighing as much as 150 tons may have to be transported. Similarly some parts of the machinery may be very long or bulky in size. Satisfactory access to site to permit easy transportation of plant and equipment is, therefore, a matter of some importance.

Similarly, since the construction of a 300 MW

atomic power station would require some 4,000 to 5,000 tons of aggregates every week (the total requirement being about 350,000-400,000 tons), availability of aggregates in the vicinity of the site could effect economies. Also the availability of fresh water for construction purposes and for the operational requirements of the station were studied. From these considerations, the sites at Tadgaon and Tarapur showed to advantage as compared with Borsi which was less accessible in view of the low lying nature of the land around, which was subjected to the effect of tidal submersion and also due to the non-availability of construction materials in the near vicinity.

Decision on Site

It will be seen from the foregoing that the only site that fulfilled the major requirements for siting the atomic power station was Tarapur and hence the choice. When, after the conclusion of the hydrographic and other surveys at the three alternative sites, it appeared that none of the sites except Tarapur could be considered seriously, consideration was given to some inland sites. As one of the primary requirements was availability of water, the site near Kakrapara Weir on the Tapi river was examined. However, it became evident that further consideration to this site could be given only after the completion of the Ukai hydro electric project as it was not a competitive site until the Ukai dam had been completed. If a second atomic power station were to be installed in the region the site near Kakrapara could be considered.

Further Investigations at Site

After the choice of Tarapur for locating the India's first atomic power station had been made, a considerable amount of detailed site data had to be collected. This included detailed contour surveys at site, detailed foundation investigations, sea water sampling, investigation for sources of fresh water, access to site, etc. This data would be required for purposes of designing of the station and also for purposes of planning the ancillary works.

Accordingly, in May 1960, a civil engineering survey team conducted detailed contour surveys at site. Simultaneously, a programme of detailed bore-hole investigations were organised and M/s. Cementation Company did the drilling work between June and August 1960. About 50 bore-holes were taken generally laid out in grid pattern in an area of 3,000 ft. × 1,700 ft. This included an area of approximately 1,400 ft. × 1,100 ft. along the exposed fore-shore as it was felt that it would be desirable to investigate the feasibility of reclaiming a part of this fore-shore area. The depth of the bore-holes varied from a minimum of about 30 ft. to about 50 ft. on an average; some bore-holes were taken deeper to depths of about 70-75 ft. Core recovery were generally good. The crushing strength determination of core samples was carried out by the Indian Institute of Technology, Powai, Bombay. The minimum crushing strength of the rock encountered was about 35.9 tons per sq. ft. (only in one case) while the maximum was of the order of 2,080 tons per sq. ft.

It would be pertinent to quote from "a note on the geology of the atomic power station site near Tarapur (Maharashtra State)" prepared by Dr. A. P. Subramaniam, Superintending Geologist, Geological Survey of India. "The proposed site area is conspicuous by the excellent exposure of bed rock comprising of volcanic breccia grading to an ash or tuff.... The site is located over an area underlain by facies of Deccan basalt formation much of it being proclastic in nature. The rocks are, however, compact, devoid of alteration, and found to have crushing strength high enough to bear heavy superstructures. The rocks at subsurface levels do not show any marked alteration or shearing suggestive of a fault zone. The site is located in an area free from seismic disturbances of noticeable intensity. It is, therefore, concluded that there are no objectionable geological features in the site area." Although the seismic disturbances in the area where the power station is to be located has been negligible in intensity, as an additional factor of safety it has been decided to adopt a value of horizontal acceleration of 10% of gravity in the design of all structures in the station.

As water from the sea would be used for purposes of condenser cooling, it was necessary to study the composition of the sea water and also the extent of suspended material in it. These factors are of considerable significance in the design of the station, in particular, on the choice of materials for condenser tubes and other components of the circulating water system. From the sample analysis that has been carried out, the silt content in the water has been found to be quite low varying from 319.9 p.p.m. to 161.3 p.p.m. giving an average of 208.6 p.p.m. for the various samples that have been so far tested. Since the samples tested so far were collected before the onset of the monsoon, the sampling and testing had been continued in the monsoon also to study seasonal variations in the silt content. Some sea bed samples were also obtained by divers. The samples obtained so far reveal that there is practically no silt in the bed samples and most of it is composed of shells of various sizes. This is a fortunate state of affairs as it may be inferred that problems of siltation are not likely to arise either at the intake or in other parts of the circulating water system.

During the hydrographic survey that was conducted by the Naval Hydrographic Office of the Indian Navy, tidal stream observations were also con-

ducted. The maximum spring rate was 2.38 knots and during the neaps 0.86 knots, during the period of observation. These are well below the value of 4 knots which has been adopted for purposes of design of the off-shore works.

The available meteorological information generally dealt with the region as a whole and the nearest meteorological observation post was only at Dahanu, about 10½ miles from the site. It was, therefore, decided to establish a small observation post near the site at a new lighthouse constructed at Ghivoli about a mile from the site. Rainfall, wind speed and direction, and air temperature measurements have commenced from June 1960. In order to study the diffusion characteristics and the likelihood of occurrence of inversion conditions, it is now proposed to erect a high steel tower to conduct micro-meteorological studies including determination of vertical temperature profiles, etc. Work on setting up of such an observation tower has been taken up.

Progress on the Project

The Enquiry Specification for the Tarapur Atomic Power Station was released on 17th October, 1960. This calls for global tenders for the design, manufacture, supply, delivery, erection, setting to work, testing and maintenance (for the maintenance period) of the complete atomic power station. The station is to have an electrical sent out capacity of 300 MW from two nuclear reactors of equal capacity. The tenderers have been given about 7½ months for preparing their tenders. It is expected that the scrutiny of tenders leading to the selection of the successful tenderer would be completed by about October 1961 and the work at site would start shortly after. According to the present plans, the first reactor of the station should be in commission four years from that date and the second about six months or so thereafter.

The tenders will form the basis for the selection of the Contractor who will be responsible for the entire works. The tenderers have been required to keep the foreign exchange content of the price to the minimum and to use or employ, to the greatest extent possible, Indian materials, locally fabricated equipment and Indian personnel. The Enquiry Specification, in particular calls for submission of details of study for the procurement of various items of plant and equipment of the station. Furthermore, it has also been suggested that all civil engineering and building works should be sub-contracted to Indian contractors.

Whilst the work on the station proper is to commence by October 1961, considerable amount of preparatory work has to be completed before then and these works have all been taken up and are in various stages of planning and execution. For example, a new road of about 3 miles has to be laid to the site and the existing road from Boisar station (which is the nearest railway station to the site) has to be widened. Facilities have to be made for establishing a siding at the Boisar station so that the contractors have enough space for storage and handling of materials before being transported to site. For purposes of supply of fresh water to the station and to the township eventually, it is intended to construct a storage or a pick-up weir on one of the rivers in the neighbourhood. Survey work in this connection has been taken up. Furthermore, a pipeline of about 12-14 miles would have to be laid for the supply of water from the river to the station site. Work in this direction has also been initiated. In the meantime, for purposes of meeting the water requirements during construction, before the river storage is available, investigations are afoot to determine sources of ground water which could be tapped as an interim measure. Construction of temporary site offices and other facilities are also expected to commence very soon. Planning of the future township for housing the operational and maintenance personnel of the station (which would number about 300 or more) has also been taken up.

Conclusions

The fishing village of Tarapur which, at one time, was the centre of considerable commercial activity, has again been regenerated due to the location of the atomic power station. In a year or so, it will be the centre of activity on one of India's most advanced engineering projects, employing some 3,000 to 4,000 people during the peak period of construction. This project should bring in its train, considerable benefits to Indian industry by helping them to orient to the needs and requirements of the atomic era. Whilst for the first station a considerable part of the plant and equipment may have to be imported by necessity, the experience gained by Indian engineers, technicians and industry would go a long way in making the country self-sufficient in the highly advanced technical skills required for atomic industry. It is gratifying to note that two of the very important preliminary phases of the project, viz. selection of site and the drawing up of the tender specifications, have been done entirely by Indian personnel. Even in more advanced countries, it has been customary to make use of specialist consultants for this purpose. Apart from the question of the saving of foreign exchange payment for such services, experience gained by the young team of engineers and scientists should go a long way to making the country self-sufficient in the specialised skills and preparing it for meeting the challenges of the atomic era.

Pierre L. Mission
Engineer Director,
Pierre Boussuges
Chief Project Design Engineer
and
Indru Advani
Project Design Engineer, Etablissements Neyrpic

Note on the Provision of Inlet Valves for Water Turbines

THE DESIGN AND LAYOUT OF HYDRO ELECTRIC projects has been the object of a searching study by engineers engaged in design of projects, as a result of which several criteria have been established, some in the form of graphs and monograms by various Authorities, such as the Bureau of Reclamation in U.S., the E.D.F. in France and other Organisations in the different parts of the world for giving assistance to Project Designers.

But by far one of the factors which has hitherto escaped this study is the question relating to the provision of Inlet Valves for Water Turbines. Hitherto, the Project Designer has proceeded on this issue more by reasons of convention prevailing in the country he is working in or by his personal intution. On other occasions after a long and laborious examination, he comes to certain conclusions which are often logical.

We find for example that for many medium head installations in Spain, the Inlet Valves upstream of the turbines are dispensed with and the only protection upstream is from the gate situated at the entry to the penstock. On the other hand this convention does not forcibly prevail in the neighbouring countries like France or Portugal where very often a Butterfly Valve is provided. What is more is that in the same country at times for installations having characteristics very much akin to each other, one is provided with an Inlet Valve whereas the other is not. The purpose of this paper is to undertake a rational examination of the provisions that are being made upstream of the turbines, especially for medium head power stations situated at the foot of the dam, and also to throw light on the new developments which have taken place, bringing greater economy to the installations.

Basic criteria for provision of Inlet Valves

In order to undertake this examination, we have at the outset made a statistical study of a large number of existing power stations spread over the world. We have prepared a graph as shown on figure 1 by choosing judicious parameters for the abcissa and the ordinate. The abcissa is represented by $\sqrt{\frac{N}{\sqrt{H}}}$

where N = output of the turbine in H.P.
H = head acting upon the turbine in metres.

This parameter is more or less a function of the diameter of the turbine runner and hence in a way represents the size of the machine.

On the ordinate is represented $\frac{L}{\sqrt{H}}$

where L = length of the penstock upstream of the turbine.
H = head in metres.

The reasons for the choice of these parameters shall be clear at a later stage when a more detailed examination is undertaken.

It will be found in the graph that the provision of Inlet Valves can be broadly divided into 3 Zones.

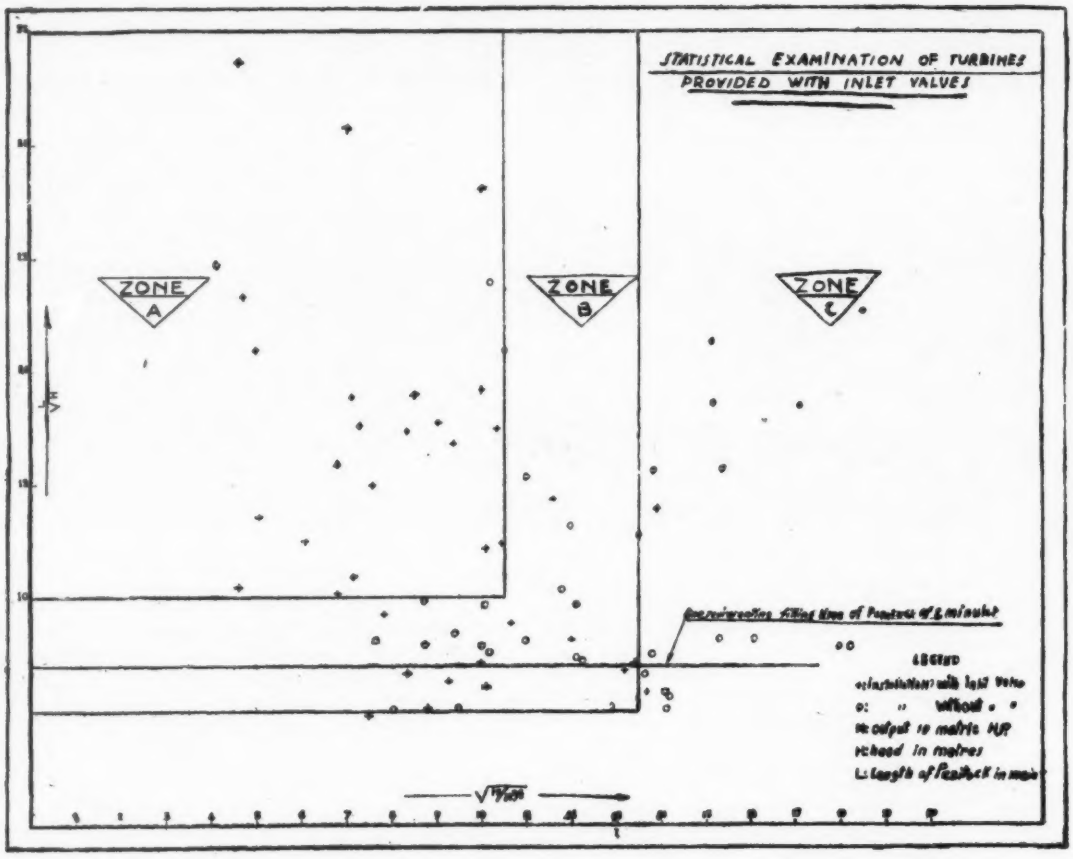
Zone A in which there prevails a preponderance of crosses representing power stations provided with Inlet Valves immediately upstream of the turbine.

Zone C with circles meaning that no such valves exist.

Zone B is the uncertain zone where there exist both turbines with and without inlet valves.

Having thus made a basic distinction between

FIGURE 1



Zones A and C, which would assist the Project Designers to secure immediately an approximate knowledge of the practice prevailing in the various Zones, we shall proceed with the detailed examination of Zone B.

Now the Inlet Valve upstream of the turbine is provided for the following reasons:

(a) to serve as a security for emergency closure,

(b) to protect the guide vanes of the turbines in case it is expected that the column of water in the penstock under full pressure shall be acting for long durations upon the guide vanes,

(c) to economise the quantity of water that would be lost by leakage past the guide vanes.

As regards the security of the installation is concerned for high head installations incorporating Pelton and Francis Turbines, an Inlet Valve usually of the Spherical or Rotary type is invariably provided since in its absence the only protection that would exist would be the head gates near the surge tank which are usually unattended and are situated a long distance from the turbine. In fact the case can be cited, namely of the Roselend Power Station in France where due to reasons of supplementary security, two Inlet Valves have been provided but in this case the head is very high of nearly 4,000 feet and the power station is underground and the designers have adopted somewhat liberal factors of security.

It is also worth mentioning that when more than one turbine is branched from the same penstock, usually a double sealing device is provided on the valve so as to permit replacement of the normal seal by closing the emergency seal and the full water pressure acting on the entire penstock, so as not to interrupt the function of the other machines. Such Power Stations are mainly covered in Zone A of this graph.

Protection of Guide Vanes for Peakload Stations

We shall now deal with the second reason, namely, the protection of the guide vanes against wear and

this examination shall deal with the controversial Zone B.

It can well be imagined that when the full water pressure is acting against the guide vanes for long periods, the guide vanes would be subjected to comparatively rapid wear since with the slightest quantity of silt in the water, which is unavoidable even with large reservoirs, the wear on the contact surfaces in the closed position shall continue to increase and in a comparatively short space of time the guide vanes shall require replacement.

This case occurs mainly in peak load power stations where the guide vanes have full water pressure acting for long periods since the turbines are required to be brought to load rapidly.

The time required for bringing the turbine to load is a very important factor for peak load power stations. This time is mainly a function of the length of the penstock for the following reason:

For an installation provided with head gates only and no Inlet Valves, it is necessary for lifting the gate to equalise water pressure on both sides of the gate, which is the usual method for "priming" the penstock which consists of either providing a by-pass valve or by cracking the gate open by means of the hoisting mechanism. In case the by-pass valve is provided, its section is approximately 1/50th of the section of the gate. Hence the time required for filling the penstock is long.

In France for peakload stations, the time required for bringing the turbine to load seldom exceeds 3 minutes. While considering the various hydraulic losses in the by-pass pipe and assuming the ratio of the gate section to the by-pass pipe of 50, and also the fact that the operating time of about 60 to 70 sec. has to be deducted for the opening of the by-pass valve and the gate, it will be found that if $\frac{L}{\sqrt{H}}$ exceeds 7, the time for bringing the turbine to load will be over 3 min. The corresponding line is represented on the graph.

In order to reduce the filling time, it will be necessary to provide a Butterly Valve immediately upstream which in a way leads to a reduction of the space to be filled up.

Another important point to be borne in mind is that should there be leakage past the guide vanes, a certain quantity of water would be lost, thereby leading to a corresponding loss of killowat hours. This factor is important for large storage reservoirs.

Use of Butterfly Valves

It would thus be seen that for peak load plants having a power station at the toe of the dam, the presence of an inlet valve in several cases may become a necessity. The valve generally used for this purpose is of the Butterfly type for reasons of economy. Nevertheless, these valves are quite expensive for large sized turbines and this fact has been a deterrant to their use. Furthermore, due to

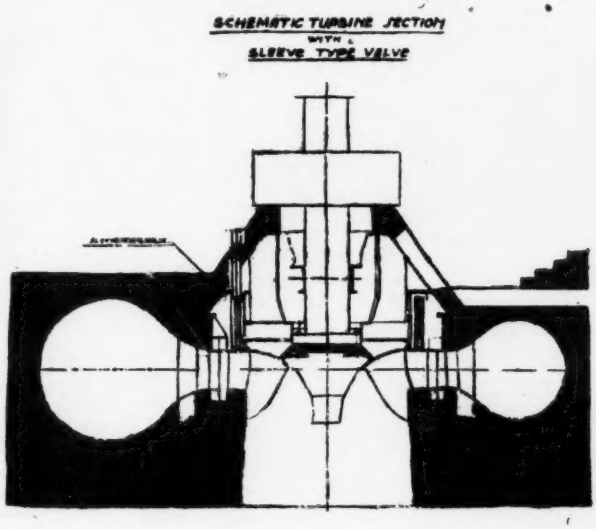
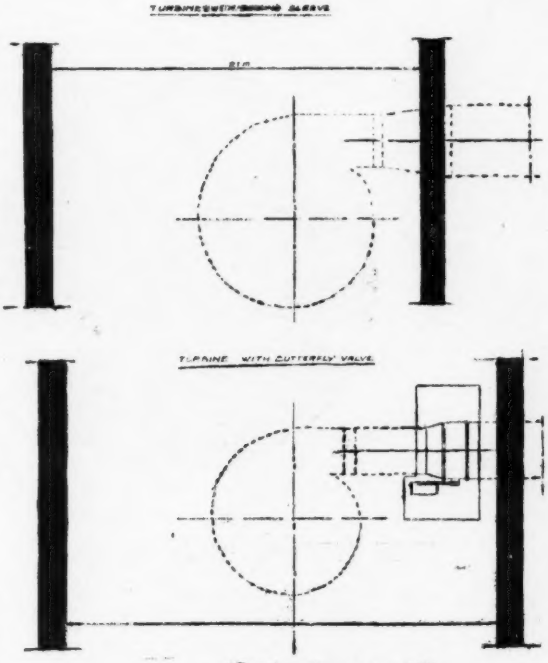


FIGURE 3

COMPARISON BETWEEN SPACE OCCUPIED BY TURBINE WITH SLIDING SLEEVE AND WITH BUTTERFLY VALVE



(Continued on page 148)

A VITAL LINK

In hydro-electric projects penstocks are a vital link between the crawling rivers and the whirling turbines. Through their sturdy steel walls water gushes at terrific velocity and pressure. to whirl the turbines and generate power. Heavy duty high pressure penstocks fabricated by IHP have provided these vital links in many major hydro-electric projects including the Rihand Dam Project, the Koyna Project, and lately the Sharavati Project.

Every day tons of vital penstocks of various diameters and thicknesses roll off the lines of the IHP factory at Hadapsar assuring a continuous supply to meet the requirements of the various hydro-electric projects planned in the 2nd & 3rd Five Year Plans.

THE INDIAN HUME PIPE CO LTD A WALCHAND GROUP INDUSTRY

Construction House, Ballard Estate, Bombay-1

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Chief
Division of Irrigation Operations
Bureau of Reclamation

Linings for Irrigation Canals

THE SANDWICH TYPE BRICK AND MORTAR CANAL LINings commonly used in India has many desirable characteristics. It would be very difficult, I believe, to improve on this type of lining, if it is placed in accordance with the sound design and construction practices evident in India. The compacted subgrade provides a stable base and the brick surface should be very durable. Moreover,, it would seem that if there is abnormal settlement the mortar joints between the bricks would provide for numerous cracks so fine that seepage should be insignificant. The hydraulic properties should be very good making possible a relatively small perimeter.

In the United States, labor costs are so high that the ordinary irrigation enterprise cannot afford to make extensive use of such linings. It was the high cost of good canal linings in the United States that caused the Bureau of Reclamation to start a program in 1946 for the study of ways and means to lower the cost of linings. Since this program has been in operation, numerous improvements have been made in linings and costs of conventional concrete linings have been reduced. In the Bureau's construction program throughout the 17 Western States, widespread use has been made of two types of low-cost canal linings: The buried membrane types and compacted earth linings. Concrete continues to be used in some areas. Conditions vary from job to job and consequently so do costs. However, the following figures probably indicate an average cost in recent years for the subgrade preparation and placement. The approximate areas shown were placed in the period 1947-1958 inclusive:

	Approximate Cost per Sq. Yd	*Approximate Amount Placed Sq. Yds.*
(1) Unreinforced concrete		
3 to 4 inches	$ 2.80	$ 21,900,000
1½ to 2 inches	1.60	
(2) Buried asphalt	1.10	7,500,000
(3) Bentonite Membranes		
(4) Compacted earth		
Large canal	1.00	5,900,000
Small canal		

Much has been written on how these linings are placed, and I will not attempt to summarize such information in this article. These comments will be made from the operation and maintenance point of view, bringing out problems that have been encountered, and questions that remain to be answered.

Concrete Lining

The outstanding properties of portland cement concrete as a construction material for hydraulic purposes have been recognized throughout the world. When concrete is used as a canal lining material excellent hydraulic properties are attained and plant growth is not a serious problem. However, being rigid, its successful utilization as a lining depends to a great extent upon a stable foundation. Even if care is used in compacting earth subgrades, moisture can and does get back of the lining and in cold climates freezing and thawing may disrupt the concrete. Similarly, disruption may occur when water collects behind the lining creating back pressure. Also concrete linings shrink and cracks are formed which permit substantial losses if the subgrade is porous and the water is free from silt and debris. In these circumstances fines in the subgrade material may be carried away by piping if there is a considerable flow of water through the cracks.

Cracks may be filled with a mastic. This is usually done as a part of the construction. Sometimes these mastics are squeezed out of the cracks and lost. Sometimes they become brittle and crumble away. These materials have been improved in recent years.

If the primary aim is permanency and lower maintenance costs, concrete may be an ideal lining material even in a cold climate. The problems mentioned above can be solved. Such a concrete lining, however, would require very careful design including a well-thought-out pattern of reinforced slabs and watertight expansion joints laid upon a thoroughly stabilized and well-drained subgrade. The cost would be comparatively high.

Concrete continues to be a popular lining material in Southwestern United States where freezing and

BURIED ASPHALT MEMBRANE CANAL LINING

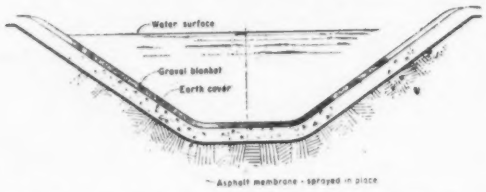
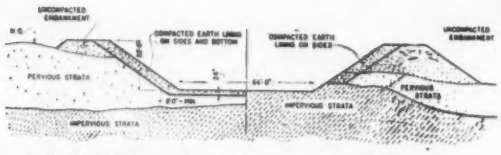


Fig. 1. Cross sectional drawing of typical installation.



TYPICAL CROSS-SECTION OF HEAVY COMPACTED EARTH LINING

Fig. 2.

thawing is not a problem and where plants grow vigorously throughout the year. Unreinforced linings two inches thick placed by a slip-form on a compacted subgrade are commonly used and give good service. Shotcrete linings approximately two inches thick are also used in this area. If these linings are placed in cold weather, there is danger of buckling when the lining is first exposed to the hot sun.

Buried Asphalt Membrane Lining

This type of lining consists of a catalytically-blown asphalt membrane about 6 to 8 mm. thick, sprayed, while hot on a smooth earth subgrade and covered with a blanket of fine soil topped by gravel. The simplicity of the design is somewhat misleading, because experience has shown that care and attention to details in construction is highly important.

The asphalt must be carefully air blown to provide a relatively high softening point without destroying its ductility and flexibility in service. We believe that it will also serve its purpose longer if phosphorous pentoxide is used as a catalyst. A few failure have been the result of a poorly prepared subgrade. Spraying a membrane entirely free from holes is surprisingly difficult if the subgrade is too wet, loose or rough. A uniform membrane will be obtained by two passes of the spray bar if the surface is reasonably smooth. In some cases, it has been necessary to bring in fine soil to obtain the desired smoothness. This may be expensive, but it is important. Lumps or pebbles loose on the subgrade surface, or voids in the surface will be the cause of holes in the membrane and there will be leakage.

The membrane should be covered with a blanket of fine soil to protect it from damage by falling rocks when the gravel cover is placed. A blanket of clean sand over the membrane seems to be unstable, so a material having some cohesiveness is preferred. Failure to place the cover with due care has resulted in a number of failures in which the membrane and the cover have slipped down the 2 to 1 slope. The percentage of such failures is very small and they seem to be due to an unusual set of circumstances.

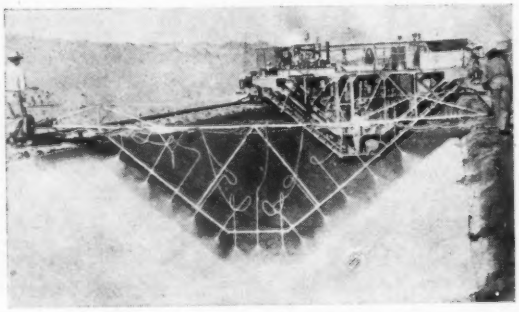
After more than 13 years of observations, it can be concluded that the buried asphalt membrane lining is giving good service, particularly where it is protected by a gravel layer on top. The gravel resists erosion and beaching at the water line. Also the gravel cover seems to reduce the growth of undesirable plants along the water line. If there has been any deterioration of the asphalt membrane in that 13-year period, it is hardly measurable. Nevertheless, the question of service life keeps coming up. It will be many years before the skeptic can be answered with facts.

We believe also that we can clean a canal lined with a buried asphalt membrane if it becomes badly silted or choked by plant growth. So far, however, our experience has been meager. It would not be wise to select a buried asphalt membrane lining for an area where drying is used to kill weeds because the membrane retains moisture in the cover. This makes drying too slow.

Buried Bentonite Membrane Lining

Bentonite membrane linings are very similar to the asphalt membrane type. Where a high quality commercial bentonite is used the membrane is formed by covering the prepared subgrade with a 1½-inch layer of granulated bentonite. If the bentonite is in a coarse form or has low swelling characteristics, the bentonite layer should be correspondingly thicker. Also the bentonite should be graded from fine to coarse particles. Otherwise the cover material will work into the open spaces before the bentonite becomes wet and leakage will result.

Again, we have found that the preparation of the subgrade has an important bearing on the success of this type of lining. If it is rough and uneven the placing of a uniform layer of dry bentonite will be diffi-



Photograph No. 1. Unreinforced 2½-inch thick concrete lining placed by rail-guided slip form and cured by application of white-pigmented compound.

Photograph No. 2. Unreinforced 2-inch thick lining being placed by subgrade-guided slip form.

cult. Furthermore, if there are numerous large voids in the subgrade due to excessive amounts of coarse material, the bentonite will work into the subgrade and become dispersed. Piping may also occur and the bentonite will be washed away by the flowing water.

In one case we believe the water in the canal contained calcium salts in sufficient quantity to cause the sodium type bentonite in the membrane to coagulate. In some sports this tendency was so pronounced that the membrane apparently lost its ability to prevent the flow of water.

Buried Plastic Membrane Lining

This type of lining has been attracting increasing attention primarily because there have been some indications that the cost of substantial amounts of the plastic membrane may be so low, that it can compete with a hot applied asphalt membrane. Numerous samples of plastic sheets have been subjected to accelerated aging in a compost for 13 years. Thus far, there have been no significant indications of deterioration. A number of test installations have been in service up to 8 years, and the results are generally satisfactory. The membrane must be of good quality and heavy enough to resist puncture and tearing. At present a thickness of 8 mils is recommended.

Thick Compacted Earth Lining

The key factor in this type of lining is the characteristics of the soils at the site. Efforts have been made to improve site soil conditions by hauling selected material and mixing it with the site material. There are limits to this approach because of the cost of hauling and mixing. In general, therefore, the use of this type of lining is limited to the suitability of soils in the area through which the canal is being constructed.

Again, it must be admitted that we lack long-term experience in evaluating the suitability of soils for such linings. There have been many apparent successes and a few failures. The presence of an adequate quantity of cohesive binder in the mixture seems to be critical. Where the soil mixture has the desired characteristics freezing and thawing forces seem to act very slowly on the lining. Where the binder is lacking, freezing and thawing, and other forces may do serious damage in a few years.

Earth linings are improved markedly by a substantial amount of gravel in the mixture or by a protective blanket of gravel. A properly graded gravel mixture will protect the surface from erosive forces and operators have observed that the growth of undesirable plants is retarded where there is a protective blanket of gravel.

Miscellaneous Linings

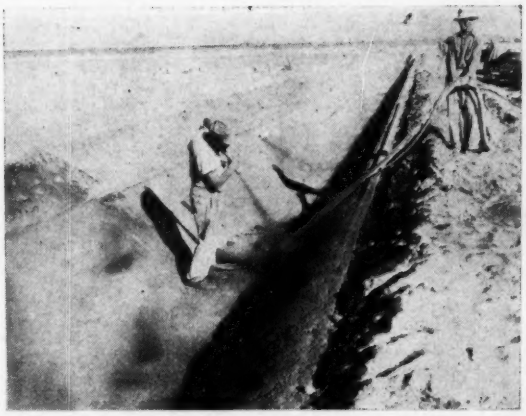
There are several other linings studied under the Lower-cost Canal Lining Program, none of which, however, are likely to be used extensively. The names and approximate amounts placed by the Bureau of Reclamation are shown in the following table:

MISCELLANEOUS EXPERIMENTAL LININGS PLACED
1947-1957

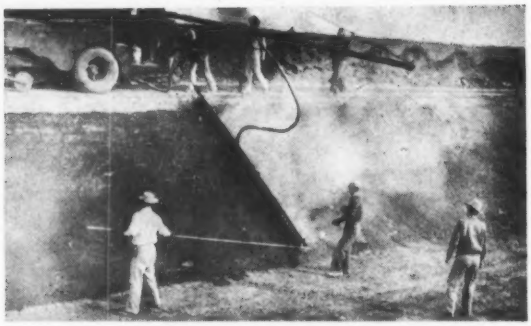
	Square Yds.	*Miles*
Hard Surface Type Linings:		
(Exposed on surface)		
Asphaltic concrete	382,000	21.0
Prefabricated heavy asphaltic sheets	71,000	6.7
Soil-cement	79,000	9.1
Asphalt macadams	14,000	1.1
Buried and Protected Membranes:		
Prefabricated lightweight asphaltic membranes	23,000	2.2
Bentonite-soil and clay membranes	6,000	0.8
Earth Type Linings:		
Thin compacted (6 to 12-inch layers)	132,000	5.9
Mixed-in-place bentonite	25,000	1.8

Future Objectives

The lower-cost linings now being used extensively in Western United States are reasonably satisfactory if properly designed and constructed. These linings



Photograph No. 3. Pneumatically applied portland cement mortar lining having a thickness of about 1½-inches.

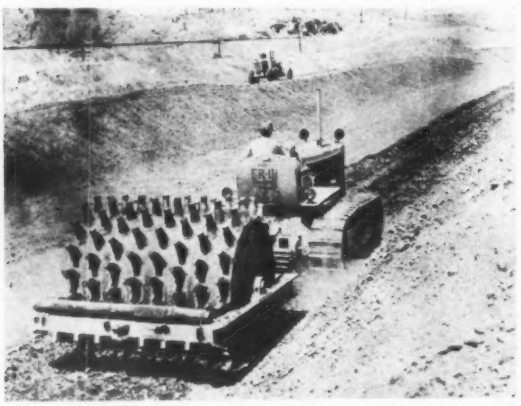


Photograph No. 4. Application of hot catalytically-blown asphalt to the subgrade for a buried asphaltic membrane lining.

cost about a dollar a square yard, varying roughly from 75 cents to $1.25. We are not likely to lower these costs significantly as long as the method used requires power and labor to overexcavate, transport, and compact. On the other hand, we have reached some measure of success. For a fraction of former costs we can make a canal virtually watertight and keep it that way for many years.

However, we are not entirely satisfied. Even with such lower losts, we cannot afford to line an entire distribution system to prevent seepage losses. Furthermore, there has been no movement on the part of irrigation organizations to use these lower cost linings in a significant portion of the thousands of miles of earth channels that are losing excessive amounts of water throughout the western United States. These losses result in high drainage costs and sometimes they mean a shortage of water. Nevertheless, irrigation organizations seem to feel that the benefits of lining seldom justify spending as much as a dollar a square yard.

If we are to bring about a truly significant reduction in seepage losses in western United States, we must discover a method that will cost a fraction of a dollar per square yard. This cannot be done by any method involving the handling of large volumes of material. To avoid these operations, we must find a way to treat the soil in place. The ideal process would be penetration of the subgrade soils by a chemical which retards the flow of water, either by plugging the voids or by holding the water on the surface of the soil particles in such quantities that movement of the water is almost stopped. Chemical compounds designed to create this latter effect are now being tested with encouraging results.



Photograph No. 5. Grader spreading earth lining material and sheepsfoot roller compacting each lift by making 10 passes for a heavy compacted earth lining.

Chemical treatment of soils in place is now a major activity in the lower cost canal lining research program. Evaluation of lower cost lining now being used and efforts to improve these linings will of course, continue indefinitely.

(Continued from page 143)

NOTE ON THE PROVISION OF INLET.....

the presence of the disc, they have to be placed at a certain distance away from the spiral casing entry in order to reduce the influence of the wake which would reduce efficiencies.

Built-in Sleeve Type Valve

In order to overcome this disadvantage of the Butterfly Valve, a new design has been produced which provided a built-in circular sleeve outside the turbine as shown in figure 2. It will be seen that this sleeve is provided between the guide vanes and the runner. This sleeve serves as a protection to the guide vanes.

As can well be imagined the provision of a built-in sleeve leads to an increase in the price of the turbine, but there is a larger saving realised in the cost of the valve. While comparing the total cost of the turbine and valve for the two cases, there is a definite economy for the case when a built-in sleeve type of arrangement is adopted. Furthermore, it will be noted on figure 3 that a considerable economy is realised in the overall breadth of the machine hall. A comprehensive study has been made on two machines of identical characteristics, namely 11,200 HP under 122 m head which are provided with a Butterfly Valve and the other is provided with a sleeve. It will be noted that the breadth of the machine hall is reduced from 26 meters to 21 metres.

Conclusions

The use of Inlet Valves for turbines situated at the foot of the dam on many occasions gives rise to some hesitation due to the high cost of Inlet Valves. From the foregoing analysis, it is evident that in such cases the peak load stations should be given particular attention. The built-in sleeve type valve is designed to meet this requirement and it gives an overall economy in the cost of the power plant and the Civil Engineering works.

OUR CONTRIBUTORS

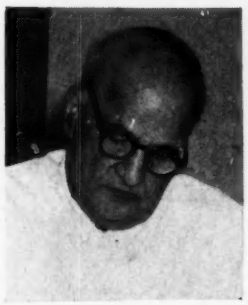
Mr. Eugene R. Black became President of the International Bank for Reconstruction and Development and Chairman of the Executive Directors on July 1, 1949.

Mr. Black first became connected with the International Bank on March 14, 1947, when he was appointed Executive Director for the United States. At that time he was a Vice President of the Chase National Bank of the City of New York, from which he resigned upon his appointment. On March 15, 1949, Mr. Black was elected a Senior Vice President of the Chase National Bank, and he returned to the Chase as of that date but continued to serve on a temporary basis as Executive Director, for the United States, of the International Bank at the request of the United States Secretary of the Treasury. On May 18, 1949, when Mr. Black was selected President of the International Bank by the Executive Directors, he resigned as Senior Vice President of the Chase Bank. Mr. Black has subsequently been selected for two more terms; his present term ends May 1, 1963.

He was educated at the University of Georgia, from which he was graduated at the age of 18. In his junior year he was elected to Phi Beta Kappa, an honorary fraternity. At 19, during the first World War, he was commissioned an ensign in the U.S. Navy.

After the war Mr. Black became associated in Atlanta with Harris, Forbes and Company, New York investment bankers. In 1931 he became manager of the Atlanta office of the Chase-Harris, Forbes Corporation, successor firm. He was appointed Assistant Vice President of that corporation in January 1933, and was placed in charge of the Atlanta, New Orleans, Houston and Dallas offices. Late in the year the firm was dissolved and Mr. Black was appointed a Second Vice President of the Chase National Bank of the City of New York, and in 1937 he became a Vice President.

Mr. V. T. Krishnamachari was Secretary to the Govt. of Madras, 1924-27; Prime Minister of Baroda State, 1927-44; Prime Minister of Jaipur, 1946-49; delegate of the United Nations Charter meeting at San Francisco and the First General Assembly, 1945-46; Chairman of the Fiscal Commission 1949-50; Member, National Planning Commission, 1950-60; Deputy Chairman Planning Commission 1953-60.



Father E. S. de Breuvery, S.J. is Ph.D. from Gregorian University, Rome. Graduated from the Institute of Political Studies, University of Paris; Head of the Economics Department and Professor of Economics in the French University of Shanghai (China) 1937-1951. Economic Adviser to the French Delegation to the United Nations Economic Commission for Asia and the Far East in Bangkok (Thailand), and then to the French Delegation to the Economic and Social Council of the United Nations in New York, 1952. Joined the United Nations Secretariat as Senior Economist in the Department of Economic Affairs, October 1952. At present, Head, Water Resources Development Centre, and Assistant Director in charge of the Resources and Transport Branch of the Department of Economic and Social Affairs.

Mr. Gordon R. Clapp. Graduated from Lawrence College, post-graduate study at the University of Chicago; received Honorary LL.D. from Lawrence College, 1947. Served as Director of Admissions and Assistant Dean of Lawrence College, 1927-32; employed by the Tennessee Valley Authority in 1933 as Assistant Director of Personnel and became Director of Personnel of that agency in 1936; served as General

Manager of the TVA from 1939 to 1946 and as Chairman of the Board to 1954; upon expiration of his service with TVA, became Deputy City Administrator of the City of New York; President of Development and Resources Corporation since its organization in 1955.

Was Chairman of the United Nations Economic Survey Mission for the Middle East, 1949; member of the President's Advisory Commission on Education, 1936 to 1939; Chairman of the Commission on Employee Relations in Public Service of the Civil Service Assembly between U.S. and Canada, 1942; President, American Society for Public Administration, 1955-56; Editor-in-Chief, *Public Administration Review*, 1943-44; onetime Visiting Lecturer, Maxwell School of Citizenship and Public Affairs, Syracuse University, Walgreen Foundation lecturer, University of Chicago, 1954, which lectures later published as *The TVA—An Approach to the Development of a Region*, University of Chicago Press, 1955. Has been member of Board of Trustees, American University of Beirut, since 1953; member of Visiting Committee of Board of Overseers, Graduate School of Public Administration, Harvard University.

Dr. P. S. Lokanathan took his D.Sc. from the London School of Economics in 1933. He taught in the University of Madras from 1925-1942. Was Editor, "Eastern Economist" Weekly from 1943 to 1947. He became Executive Secretary of the U.N. Economic Commission for Asia and Far East at Bangkok from 1947 to 1956. At present is Director-General, National Council of Applied Economic Research, New Delhi.

He has been a member of several professional bodies like Consultative Committee of Economists.

Delegate to the World Business Conference, at Rye., N.Y. 1944 and to the Pacific Relations Conference, Hot Springs, Jan 1945.

Secretary, Indian Industrialists Mission to U.K. and U.S.A. 1945.

Indian Delegate, Preparatory Committee, International Trade Conference, London and Geneva.

Chairman, Governing Body, National Productivity Council.

Chairman, Advisory Board, Demographic Training and Research Centre.

Chairman, Agricultural Economics Committee, Indian Council of Agricultural Research.

Member, Board of Research and Advisory Board, Indian Council of Agricultural Research.

Member, Central Wage Board for Sugar Industry.

Member, Court of Governors, Administrative Staff College of India.

Member, Local Board, State Bank of India.

Vice-President, Indian Council of World Affairs.

Sir Josiah Eccles. He was educated at Queen's University, Belfast, where he obtained a B.Sc. degree in Engineering.

He served with the Royal Artillery in the European War 1914-1918.

He began his career with Metropolitan-Vickers Electrical Company Limited. In 1928, he joined the Edinburgh Corporation Electricity Department, becoming Engineer and Manager in 1940. At the end of 1943 he was appointed City Electrical Engineer in Liverpool, which post he held until the Electricity Supply Industry was nationalised in 1948, when he was appointed Chairman of the Merseyside and North Wales Electricity Board. In January 1954, he was appointed Deputy Chairman (Operations) of the British Electricity Authority.

With the reorganisation of the Industry in 1957, Sir Josiah was appointed Deputy Chairman of the Electricity Council.

He was President of the Institution of Electrical Engineers in 1954/55; President of the 1957 British Electrical Power Convention.

He is a past President of the Incorporated Municipal Electrical Association; the British Electrical Development Association and the British Electrical and Allied Industries Research Association.

Dr. N. A. Karaulov is D.Sc. in Technology and a member of the Academy of Sciences, U.S.S.R.

Mr. W. L. Voorduin is Vice-President and Director of Engineering, Development and Resources Corporation which has projects in Iran, Ghana, Argentina and Peru. Between 1949-56 he was Chief Hydraulic Engineer, Gibbs and Hill, Inc., of New York; He was member, later Chairman, Central Technical Power Board, Government of India from 1944 to 1948. Associate Hydraulic Engineer, later Head Civil Engineer, Tennessee Valley Authority between 1934 and 1944.

Mr. Kanwar Sain took his engineering degree with distinction in 1922 from Roorkee and joined the ISE in 1923. He worked in the Punjab irrigation upto 1947 with great credit. He was associated with the designs and construction of Sulemanki headworks and the canal structures on the Pakpattan Canal. He was also associated with the detailed design of Panjnad headworks on the Sutlej Valley Project. In 1935 he undertook the preparation of the Haveli and Thal Projects. He was chosen as the first Director of the Central Designs Office for these two projects. In 1939 he went to U.S.A. to study the design and construction techniques for the Bhakra Dam. He represented the Punjab before the Indus River Commission from 1940 to 1942 and became Director of Irrigation Research in 1943. In 1947 he was appointed Chief Engineer of the Bikaner State and soon became Member (Designs) of the CWINC at Delhi. In 1951 he was appointed Chief Engineer of the Hirakud Dam Project, after which he became the Chairman of the CW & PC. On retirement from the Chairmanship he became Chairman and Administrator of the Rajasthan Canals Project which is the largest of its kind in the world.

Mr. Sain has travelled extensively and has held important positions in the professional field. He led a delegation of experts to the Soviet Union in 1955 and a year earlier led a commission to China to study its river valley project methods. He has been an adviser to the Flood Control Committee of the ECAFE and has delivered several lectures under its auspices. He was President of the International Arid Areas Conference held in New Mexico and was also consultant to the U.N. in the Mekong Project.

Lieut. General Emerson C. Itschner is Chief of Engineers, United States Army. He is officially a resident of the State of Washington, although now he is living at Fory Myer, Virginia, across the Potomac from the Nation's capital. He is a graduate of the United States Military Academy, West Point, Class of 1924, and of Cornell University, 1926.

General Itschner has served in many engineering positions in the Corps of Engineers, on both its military and civil works activities. In World War II he was Engineer of the Advance Section Communications zone in Europe. During the first year and a half of the Korean War he was Engineer of the I Crops. He was Division Engineer, North Pacific Division, Corps of Engineers from 1952 to 1953, and he served as Assistant Chief of Engineers for Civil works from 1953 until being appointed Chief of Engineers on 1 October 1956. The White House announced on 6 May 1960 that the President had approved an extension for two years of the normal four year term of General Itschneras Chief of Engineers.

Dr.Hassan Zaky is Member of the Supreme Committee of the Sadd-el-Aali and President of the Sadd-el-Aali Executive Organisation.

Mr. M. Hayath graduated in Engineering from the University of Mysore in 1923. He joined the Mysore Public Works Department in 1924. Deputed by the Government of Mysore Foreign Training from 1927 to 1930 he obtained the B. S. E. E. degree from the Union University, Schenectady, New York. From 1941 to 1953 he was the Chief Electrical Engineer to the Government of Mysore. He served as Power Consultant to ECAFE at Bangkok for 14 months in 1951-52. After retiring from the Mysore service, he joined the ECAFE again in January 1953 as Chief of Power Division. He returned from Bangkok in 1954 and joined the Central Water and Power Commission as Member (Hydro Electric). He has taken over as Chairman of the Commission from 15th October, 1958.

Dr. Charles Jaeger was born in 1901 in Zurich, Switzerland, and received Secondary Education in Switzerland and Buenos Aires (Argentine). Obtained Diploma in Civil Engineering, Zurich Institute of Technology, 1924 and Doctor Thesis (Zurich) (1933). Professeur agrege (Zurich) (1943). Since 1946 special Lecturer on Engineering Fluid Mechanics and Hydro-Power Structures at the

Imperial College, London University. From 1929-1946, Scientific Adviser to the Hydraulic Research Laboratory, Zurich (Prof. Mayer Peter). Since 1946, Consulting Engineer to the English Electric Company.

Dr. Jaeger has published well over 100 books and papers on Hydraulics, Fluid Mechanics, and Hydro Power Structures.

1933: Theorie Generale de Coup de Belier

1946/57: Engineering Fluid Mechanics

1959: Contribution of 4 chapters to Guthrie Brown's "Hydro-Electric Engineering Practice".

Numerous papers on the Theory of Energy and Momentum of Flow in Open Channels, Surge Tank Design, Surge Tank Stability, Water Hammer, Arch Dams, Underground Power Stations, Power House Design, Economics of Hydraulic Designs and of Pumped Storage, Electric System Load Factor Analysis, etc.

Member of the Sub-Committee on Underground Works (Congress on Large Dams), Associate Member of the American Committee on Water Hammer (1933).

Mr. N. D. Gulhati was educated at the Government College, Lahore, and Thomson Civil Engineering College, Roorkee. Appointed to the Punjab Irrigation Branch as Apprentice Engineer in October 1926. Appointed to the Indian Service of Engineers (I. S. E.) in October 1927. From 1926 to 1941 engaged in surveys, design, construction, maintenance and re-modelling of canals, drainages, headworks and river works. From 1941 to 1945 he was Under-Secretary to the Govt. of Punjab. Public Works Deptt. (Irrigation Branch). From 1945 to 1948 became Secretary, Central Board of Irrigation. Joined the Govt. of India in October 1948 as Deputy Secretary, later promoted as Joint Secretary and then as Additional Secretary. From 1950 to 1953 he was Chief of the Natural Resources Division of the Planning Commission (in charge of the First Five-year Plan for Irrigation and Power and development of Mineral Resources). From 1953 to date he was Indian Representative on the Indus Waters discussions with Pakistan under the good offices of the International Bank for Reconstruction and Development.

Author of several technical articles, papers and books. Recipient of the Kennedy Gold Medal (1945) and the Punjab Engineering Congress Medal (1942).

He is also Secretary-General of International Commission on Irrigation and Drainage from 1950 to 1957; Vice-President of the International Commission on Irrigation and Drainage from 1957 to 1960; President of the International Commission on Irrigation and Drainage from June 1960 for three years.

Prof. Mario G. Salvadori received Doctorate in Civil Engineering in the University of Rome in 1930. Doctor in Mathematics in the University of Rome, 1932, Libero Docente in Theory of Structures in 1937. He is Professor of Civil Engineering in the Columbia University, U. S. A. since 1946; Professor of Architecture, Columbia University, since 1960. He received Honorary Degree in Civil Engineering from the University of Minas Gerais, Brazil. Author of over 80 papers on applied mathematics, applied mechanics and structures. Author of 3 books on applied mathematics, one of which is translated into Russian, Chinese, Portuguese and Spanish. Partner of Panero-Weidlinger-Salvadori, consulting engineers, with offices in New York, Rome, Paris and Bogota.

Mr. Grant Bloodgood was named Assistant Commissioner and Chief Engineer of the Bureau of Reclamation in February 1958. He directs the Bureau's engineering activities in water resources development in the 17 Western States and Alaska of the United States. His offices are at the Bureau's engineering center at Denver, Colorado.

Mr. Bloodgood graduated from the University of Nebraska in 1920. He began his Bureau of Reclamation career on the North Platte and Riverton Projects in Nebraska and Wyoming. He was in private engineering work from 1925 to 1929, including the location and construction of a canal and lateral system for a 40,000 acre irrigation project in Mexico. He returned to the Bureau of Reclamation in 1929, working on the Riverton Project and later going to the Boulder Canyon Project, where he was in charge of layout and estimates during construction of Hoover Dam and Powerplant. He was, successively, Resident Engineer for construction of the All-American Canal, the Gial Project, and the Kennett Division of the Central Valley Project, including Shasta and Keswick Dams and Powerplants.

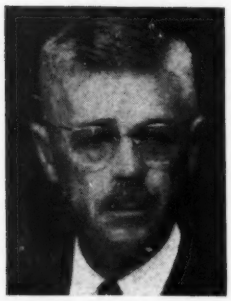
His military service with the Corps of Engineers

in World War II included 37 months overseas in the Persian Gulf Command and the European Theater of Operations. He was awarded the Army Legion of Merit in 1944. He also saw service in World War I.

Returning to the Bureau of Reclamation as Chief of the Construction Engineering Division in Denver in 1946, he later became Assistant Chief and then Chief Construction Engineer. He was named Associate Chief Engineer in January 1954.

He is a member of the American Society of Civil Engineers, Society of American Military Engineers, American Concrete Institute, and United States Committee on Large Dams. He was awarded the Department of the Interior Gold medal for distinguished service.

Mr. A. M. Komora graduated from the University of Michigan, 1924, B.Sc. in CE. Fellow ASCE. Professional Experience: Field Engineer on the construction of Hodenpyl Dam on the Manistee River for the Consumers Power Co. 1924-25. Hydraulic Design Engineer, Consumers Power Co. in Jackson, Michigan 1925-29. Construction Engineer on the construction of Hardy Dam on the Muskegon River for Consumers Power Co. 1929-31. Steam Plant Designing Engineer for the Detroit Edison Company, Detroit, Michigan 1931-33. Engineer Director for the Corporation Peruana del Santa in Lima, Peru, on the design of a large hydro-electric project in Peru, South America. Project Manager, Tennessee Valley Authority, Knoxville, Tennessee (1934-1943). Chief Engineer on the Damodar Valley Project in India 1950-1959. Hydraulic Engineer for the Bechtel Corporation of San Francisco, California. 1959 to date.



B. M. Abbas is Commissioner, Water Development, East Pakistan Water and Power Development Authority.

Mr. Ervin Nonveiller, is a civil engineering graduate of the Technical University in Vienna (1932). For several years he worked with various civil engineering firms in Yugoslavia on different construction jobs. During World War II he joined the liberation forces of his country, and was active after the War on reconstruction works on bridges and roads destroyed during the War. From 1946 Mr. Nonveiller worked on the construction of hydroelectric power plants in Yugoslavia as manager of a specialised construction firm. In 1952 he joined Messrs. Geoistrazivanja in Zagreb, Yugoslavia for whom he organised the Soil mechanics and foundation division. In 1957 he visited India in connection with grouting works on Kotah Barrage.

Mr. Nonveiller participated actively at various meetings of the International Soil Mechanics Society and of the International Commission on High Dams. He published many papers at home and abroad.

Dr. Nolini Kanto Bose is M.Sc. of the Calcutta University, Ph.D. of the Gottingen University, Companion of the Institute of Engineers (India), Fellow of the National Institute (India). He has been lecturer in Mathematics, University of Dacca from 1921 to 1924; Reader in Mathematics in the University of Aligarh from 1925 to 1927. He was Griffith Scholar of the Calcutta University in 1925. He joined service as Mathematical Officer, Irrigation Research Institute, Lahore, Punjab in 1927. Rose up to Director, Irrigation Research Institute, Lahore, Punjab in 1942. Became first Director, River Research Institute, Bengal from 1943 to 1947 which post he continued after Partition up to 1956 in West Bengal. On retirement he was posted as Officer on Special Duty C.W.P.C., Government of India: 1957-1958. He was Member-Secretary, Damodar Flood Enquiry Committee: 1943-1945; Adviser, Damodar Valley Corporation: 1949-1958; Member Kosi Project Ad-hoc Committee, Government of India, 1952; Consultant, Economic Commission for Asia and the Far East (Flood Wing), United Nations Organisation, Bangkok, 1954; Member, Hooghly Expert Committee, Government of India: 1954; Member-Secretary, West Bengal Flood Enquiry Committee:

1956-57; Member, West Bengal Flood Enquiry Committee: 1959-60; Member, Team of Experts, Kosi Project, Government of India, 1957; Special Officer, Government of West Bengal: 1958-1960; He was also Research Professor, Flood Research, Indian Statistical Institute, Calcutta: 1958-1960; and Member, Indian Delegation to Pakistan for Exchange of data relating to the Ganga River Basin, 1959.

Mr. Richard D. Harza Vice President and new business manager of Harza Engineering Company, graduated from Northwestern University in 1944 and received his Master's Degree from the same school in 1947. During 1945-46 he was an Ensign in the U.S. Navy. In 1947 he joined the Harza Engineering Company and has had experience on the design and construction of dams and power plants, irrigation and reclamation schemes. During this period, he has carried out engineering assignments in Greece, Turkey, France, Iraq, Iran, Pakistan, India, Suriname, El Salvador, and the Belgian Congo. He holds a Professional Engineer's license in the States of Alaska, Illinois, Mississippi, and Washington, and is an Associate Member of the American Society of Civil Engineers.

Mr. Digambar Vasudeo Joglekar after graduating in Engineering from the Bombay University in 1921, joined the Bombay Government in their Research Department and since then has been engaged on Hydraulic Research at the Hydraulic Research Station at Khadakwasla near Poona now known as the Central Water and Power Research Station, Poona, except for three years from 1923-26 when he was engaged on reclaiming waterlogged and salt affected areas by drainage schemes on the Godavari Canals and related problems. He served under Bombay Government till 1937 and thereafter under the Government of India till 1957, the last ten years of his service being as the Director of the Research Station at Khadakwasla. He is now working Adviser to the Central Board of Irrigation and Power for co-ordinating research work which is being carried out by 19 Research Stations in India on Fundamental and Basic Research problems connected with River Valley Projects and Flood control works.

He attended the Congresses of the International Association for Hydraulic Research held at Grenoble (France) in 1949, at the Hague in 1955 and at Montreal in 1959 and has been elected as the Vice President of the Association for the years 1960 and 61.

Sri. D. V. Joglekar has devoted his entire career on Hydraulic Research and has done pioneering work on river training. He has been mainly responsible for building up the Central Water and Power Research Station, Poona, to its present status. While successfully solving several problems he has evolved a new approach to such studies as curvature of flow for sand control, repelling spurs pointing upstream for protecting towns, bridges and other structures, study of influence of silt and sand on river behaviour, study of coastal engineering and harbour problems, etc. The Central Board of Irrigation and Power publication "River Behaviour, Control and Training" prepared under his guidance is a substantial contribution in River Hydraulics. This publication has been acclaimed internationally as a Standard Manual.

In appreciation of his work, the President of India was pleased to confer on him the award of PADMA SHRI in 1955. He was also awarded a Gold Medal and Cash Prize of the Union Ministry of Irrigation and Power placed at the disposal of the Institution of Engineers (India) for his paper entitled "Use of Hydraulic Models in River training, flood control, and other engineering works" which was published in the Journal of the Institution in 1959.

Mr. M. N. Chakravarti who relinquished his office as Member (Staff), Railway Board, with effect from July 30, 1959, had over 31 years' railway service behind him.

He joined the railways on March 5, 1928. By 1933, he was dealing with administrative matters and freight rates at the headquarters of the former North Railway at Lahore. During the war, he was transferred to Karachi to perform vital duties relating to the movement of goods from the port.

From Karachi, Mr. Chakravarti went to the Walton School at Lahore, now in Pakistan, to train officers and men, a job he had to leave just before Partition intervened in 1947. During the same year he became secretary of the Indian Railways Enquiry

Committee under the Chairmanship of Shri K. C. Neogy and later Pandit H. N. Kunzru.

Mr. Chakravarti then became Chief Director of Food Movements in the Ministry of Food and Agriculture, where he was called upon to fight the great Bihar Famine of 1951. On return from the Ministry of Food and Agriculture, Mr. Chakravarti was appointed Senior Deputy General Manager of the Eastern Railway. Later, he headed the Efficiency Bureau in the Railway Board as its Director, and here he produced several valuable studies.

He took over as General Manager of the Central Railway on January 18, 1955 and came to the Board's office on July 1, 1958, when he took over as Member (Staff).

Mr. Pierre L Misson is the Engineer Director of Ets. Neyrpic who are leading manufacturers in the field of hydraulic equipment. Mr. Misson was the founder of Neyrpic organisation in North Africa. He has been associated with Hydro Electric Developments all over the world. In particular he had the occasion to work upon the development of Axial Flow Machines dealt in this article.

Mr. Pierre Boussuges

Mr. Pierre Boussuges is the Chief Projects Engineer of Etablissements Neyrpic and he is at the same time professor at the Grenoble Institute for Electricity and Hydraulics. His treatise on hydraulic machines is considered to be one of the valuable text-books in this field.

Mr. Indru Advani

Mr. Indru Advani has been working on the design of projects since several years. He has been associated with several projects in the world, but his particular interest resides with projects in India.

Mr. Hollis Sanford is Chief of the Bureau of Reclamation's Division of Irrigation Operations, at Denver, Colorado, which provides technical guidance and coordination for the Bureau's entire irrigation operation and maintenance program. He came to Denver as Assistant Chief of the Division in 1954 after serving from 1950 as Assistant Director of the Division of Operations and Maintenance at Washington, D.C. He was named to his present position in 1956.

Mr. Sanford began his career in the Bureau of Reclamation in 1928 when he came to work in concrete and earth construction on the Yakima Project. This was followed by assignments to the Owyhee and Boulder Canyon Projects and the Denver office of the Bureau until 1936, when he was assigned to the Regional office at Boise, Idaho, as associate engineer. In 1941, he became district conservationist for the Boise office.

In 1945, he was appointed Assistant Regional Supervisor of Operation and Maintenance at Boise, a position he held to 1950, when he was made Assistant Director of the Division of Operation and Maintenance at Washington, D.C. Activities of the Irrigation Operations Division range from studies of farm water deliveries and losses to guidance on the preparation of operation and maintenance estimates for project planning. The Division coordinates the periodic inspections of Bureau structures and is responsible for providing standards for the safety, adequacy, and continued improvement of Bureau structures from the irrigation operation and maintenance standpoint.

Prof. Koichi Aki graduated from the civil engineering department, University of Tokyo, 1926. Appointed engineer of Ministry of Home Affairs, 1926; engaged in the improvement works of Kinu and Fuji Rivers till 1936. From 1936 to 1939, engaged in research and planning work at hydraulic laboratory, Ministry of Home Affairs. From 1939 to 1944, engaged in research and planning work of major rivers in Japan and in China, including Yellow River and Yangtze Delta areas.

Awarded the Doctor's degree of Engineering,

University of Tokyo, for the theory of river regime, in 1943. Appointed a Professor of the Second Engineering Faculty, University of Tokyo from 1944 to 1951. Since then, engaged in research work on the movement of flood flow at the Institute of Industrial Science, University of Tokyo. Lectured on hydraulic engineering at the Engineering Faculty and postgraduate course, University of Tokyo from 1954 to 1960.

During 1946-1948, served as the Director of the Public Works Research Institute, Ministry of Construction. From 1948 to 1951, served as the Chief Secretary to Resources Council, Economic Stabilization Board. Appointed the Vice-Chairman of Resources Council, 1951, (now belongs to Prime Minister's Office). Appointed the Science Councilor, Science and Technics Agency, 1956.

Appointed the Chief, Bureau of Flood Control and Water Resources Development, Economic Committee for Asia and Far East, United Nations in Bangkok, November 1960.

Among trips he made holding importance to his career to date are that he visited thirteen times during the years from 1939 to 1944; to the United States many times since 1950; to India in 1951 for six weeks; to Thailand for ten weeks as a technical consultant to ECAFE in 1952-1953; to Switzerland in 1955 to attend the International Conference of Atomic Energy's Peace Utilization etc.

He has written many theses and books: Theory of River Regime (1943), Engineering of River Improvement Works (1952), Resources Problems in Japan (1952, awarded the Mainichi Press Prize), Story of Flood Flow (1952), Japan's Flood Damages (1952) etc.

Robert F. Edbrooke is Assistant Project Manager of Messrs Harza Engineering Company, U.S.A.

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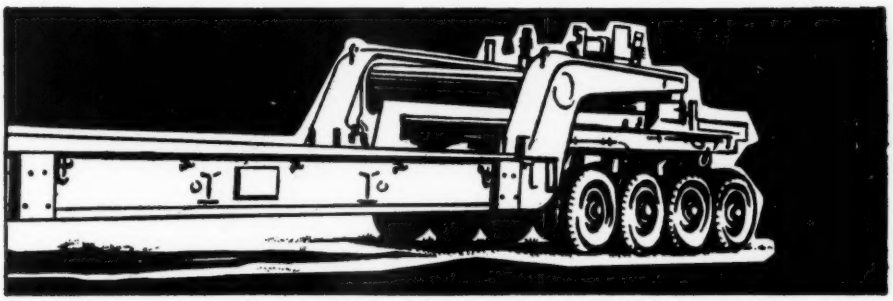

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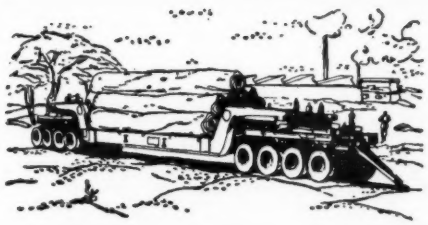

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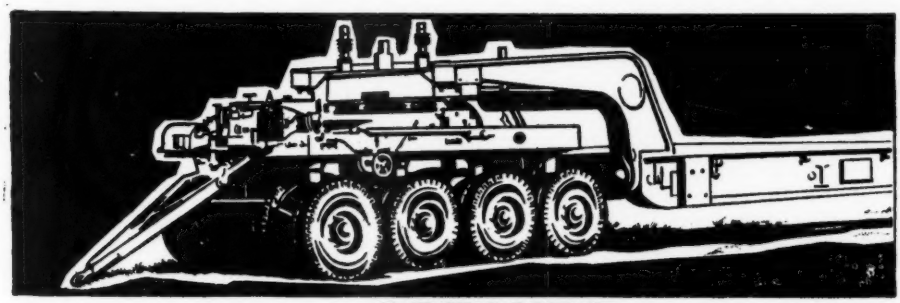

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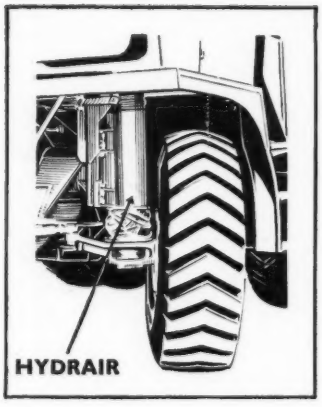

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